

**AN INVESTIGATION OF THE DISTRIBUTION OF
STRESS OVER WIDE REINFORCED CONCRETE BEAMS
UNDER CONCENTRATED LOADS**

BY

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THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

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COLLEGE OF ENGINEERING.

May 24, 1912

This is to certify that the thesis of LYMAN LIONEL LIVINGSTON entitled AN INVESTIGATION OF THE DISTRIBUTION OF STRESS OVER WIDE REINFORCED CONCRETE BEAMS UNDER CONCENTRATED LOADS was prepared under my personal supervision; and I recommend that it be approved as meeting this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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I. Introduction

1. Purpose.- The purpose of this thesis is to investigate the effect of concentrated loads on wide beams, and to determine the amount of transverse reinforcement required in a beam of given dimensions, in order to have the longitudinal and transverse steel fail at the same time. Tests were made in 1910, and 1911, at the University of Illinois for the same purpose. The tests of the 1910 series were made by K.E. Robinson and are reported in his thesis entitled, "Tests of Reinforced Concrete Beams: Effect of Lateral Distribution of Loads." The tests made in 1911 were by E.J. Schell and are reported in his thesis entitled, "The Effect of Lateral Distribution of Loads over Wide Reinforced Concrete Beams." Their tests were made on beams of different proportions between lengths, widths, and thickness, and with different proportions of the widths loaded.

In the beams of this thesis, the widths, and the percentages of longitudinal and transverse reinforcement were the variables. The span was 48 inches and the depth was six inches in all cases with the exception of beam No. 750.1. Its depth was made only three inches in order to insure tension failure in the steel, and to afford a basis for direct comparison with the results of the previous tests. In all three series the load was applied at the one-third points of the span. The only exceptions to this are beams No. 749.1 and 749.2 of the 1911 series. In planning each series of tests an attempt was made to design the test beams of one series so that the tests would be similar in as many respects as possible, to those of the preceding



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series, in order to afford a direct method of comparing results.

2. Supervision.- The tests described in this thesis were made under the direction of the Illinois Engineering Experiment Station staff, and form a part of a more elaborate investigation of reinforced concrete beams. The interpretation of results and the ^econclusions drawn are original with the writer of this thesis.

3. Acknowledgment.- Mr. T.G.Burgess, a senior student of the University of Illinois, assisted in the greater part of the testing work, and it was to have been a part of his thesis, but owing to his sickness and death before the testing was finished, the work was completed by the writer, with the assistance of men engaged by the Experiment Station staff to do the mechanical work.

II. Materials, Test Prices, and Method of Testing.

4. Materials.- The sand and stone were ordered under the same specifications as those given in the bulletins of the Engineering Experiment Station.

Stone.- The stone was a good quality of limestone from Kankakee, Illinois, ordered screened through a one-inch and over a one-quarter inch screen, and was graded as shown in Table I. page 3.

Sand.- The sand used came from near the Wabash river at Attica, Indiana. It was relatively free from dirt and was graded as shown in Table II. page 3 .

Table I
Mechanical Analysis of Stone.

Average of 5 samples

Size of Square Opening	Separation Size Inches	Per Cent Passing
1 in.	--	100.
3/4 "	--	95.5
1/2 "	--	66.7
3/8 "	--	46.3
No.3	0.28	25.9
No.5	0.174	8.1
No.10	0.091	3.4

Table II
Mechanical Analysis of Sand.

Average of 5 samples

Sieve No.	Separation Size Inches	Per Cent Passing
3	0.28	100.
5	.174	88.
10	.091	54.3
12	.067	47.5
16	--	41.7
18	.043	32.9
30	.027	21.2
40	.019	13.3
50	.013	5.1
74	.009	2.7
150	--	1.0

Cement.- Universal Portland Cement was used. Tests on this cement showed the initial set to occur at 3 hr. 5 min. and final set at 6 hr. 32 min. after mixing. Sieve tests showed 97.2% passing a No.100 sieve and 81.8% passing a No.200 sieve. The test of the briquettes are shown in Table III. These tests were made according to standard methods by Mr. B.L.Bowling at the Cement Testing Laboratory, University of Illinois.

Table III

Briquette Test of Universal Portland Cement.

Each value is the average of five tests.

Loads are given in lb. per. sq. in.

Sample No.	Date	Neat 7 Days	Cement 28 days	1 - 3 7 Days	Mortar 28 Days
1	Oct. 25, 1911	585	685	239	315
2	Nov. 11, 1911	577	694	225	297
3	Dec. 7, 1911	691	715	242	306
4	Dec. 22, 1911	617	792	231	326
5	Jan. 10, 1912	588	672	246	333
6	Feb. 12, 1912	612	758	253	323
7	Feb. 28, 1912	698	884	287	372
	Average	<u>624</u>	<u>743</u>	<u>246</u>	<u>325</u>

Concrete.- A 1-2-4 mixture was used for all the specimens. Men in the employ of the Experiment Station, who were accustomed to making the concrete mixed the materials and made the test beams. The mixing was done with shovels by hand.

Steel.- All the steel used was mild steel, and came from the Illinois Steel Company. The yield point was at a stress of about 42,000 lb. per. sq. in.

5. Test Beams.- The summary sheet page 16 gives the dimensions of the test beams and the amounts of reinforcement used. Page 5 shows how the rods were placed in the beams, and the lengths of the different bent up rods.

6. Method of Making the Beams.- The beams were made directly on the concrete floor of the laboratory, a strip of building paper being laid beneath the forms to prevent the concrete adhering to the floor. The forms used were the ordinary wooden knock-down type.

7. Storage.- The beams were stored in a room the temperature of which was from 60 F. to 70 F. They were tested

Sketches Showing Spacing of Rods
in beams.

Beam No.	Size ft Rods	Type of Rod			
		A. No.	B. No.	C. No.	D. No.
750.	$\frac{3}{8}$	14.	0	0	0
751.	"	4	4	4	2
752.	$\frac{7}{16}$	4	4	4	3
753.	"	8	8	7	6
754.	"	"	"	"	"
755.2	"	"	"	"	"
756.	$\frac{1}{2}$	9	8	8	8
757.	"	"	"	"	"
758.1	"	11	11	11	11
759.	$\frac{3}{8}$	6	4	4	6
760.	"	"	"	"	"
761.	"	"	"	"	"
762.	"	"	"	"	"
763.2	$\frac{7}{16}$	"	"	"	"
764.	"	"	"	"	"
765.	$\frac{1}{2}$	6	6	6	5-
766.	"	"	"	"	"
767.	$\frac{7}{16}$	10	10	10	9
768.1	$\frac{3}{8}$	8	$\frac{[E]}{4}$	$\frac{[E]}{6}$	$\frac{[E]}{4}$
755.1	$\frac{7}{16}$	9	8	6	6
763.1	"	6	6	4	4

Edge

4

A B C D 751 D A B C

A B C D 752 D A B C D

A B C D 753-52 C D A B C

A B C D 756-7 A B C D A

A B C D 758 C D A C

A B C D 759-64 C D A C

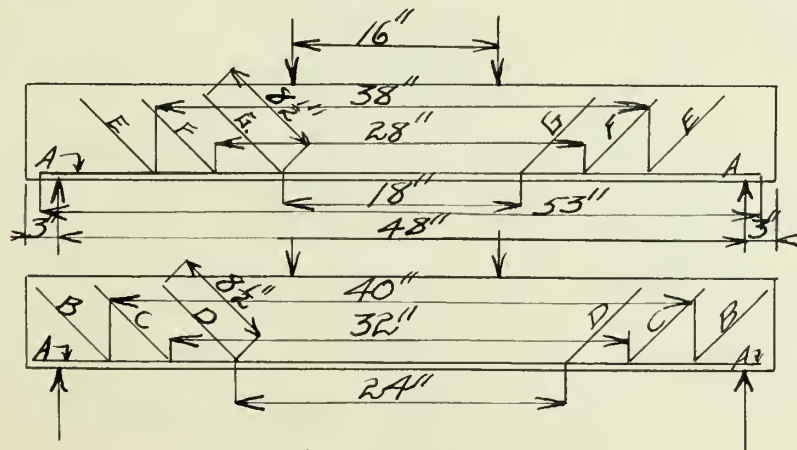
A B C D 765-66 D A B C D

A B C D 767 D A B C D

A A F F F 768 F D A F

A F F D 7551 F D A F A

A F F D 763.1 F D A F



Side Elevation

End View

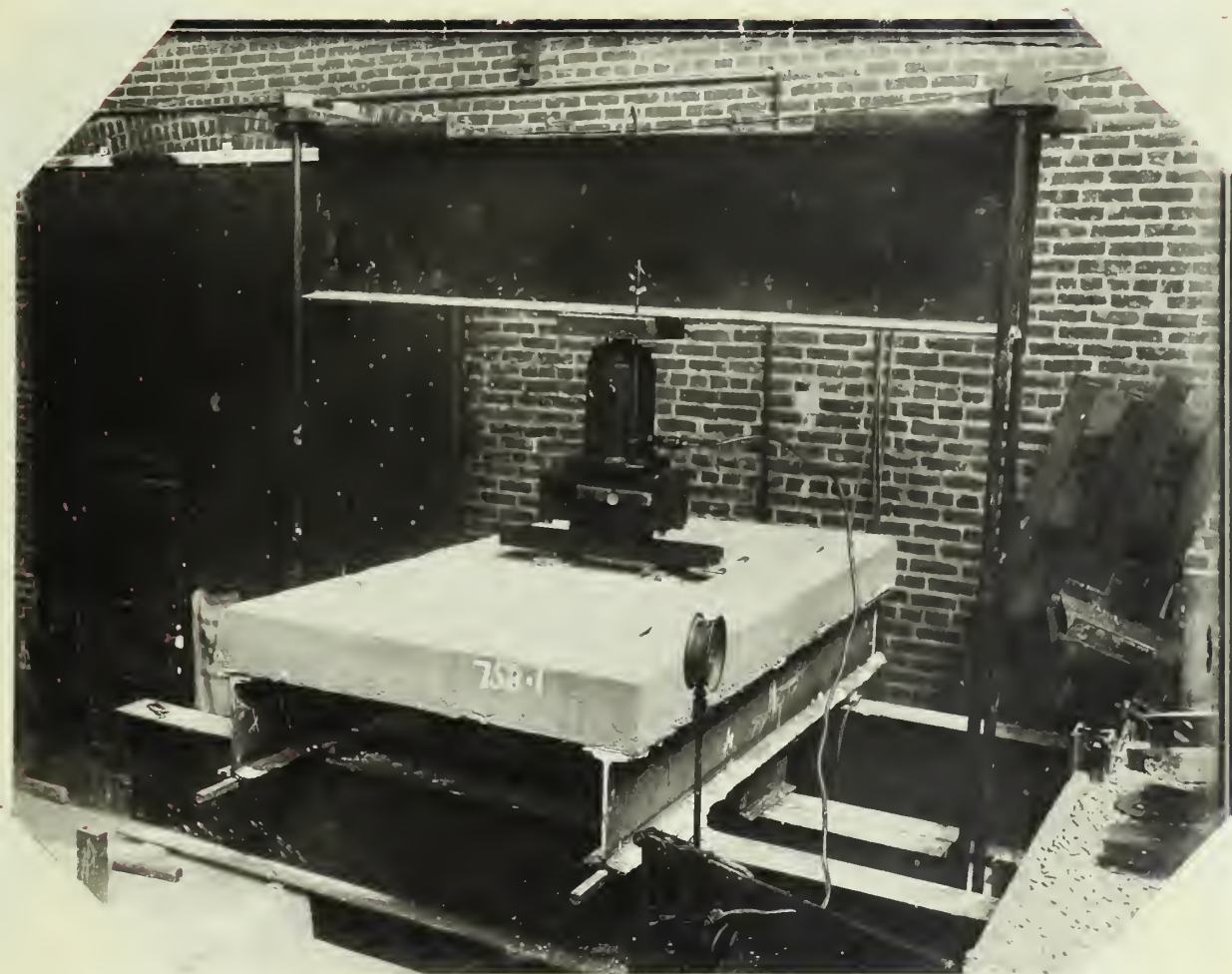
Prod	Total / en.
A	53 in
B	57 ..
C	49 ..
D	41 ..
E	55 ..
F	43 ..
G	35 ..

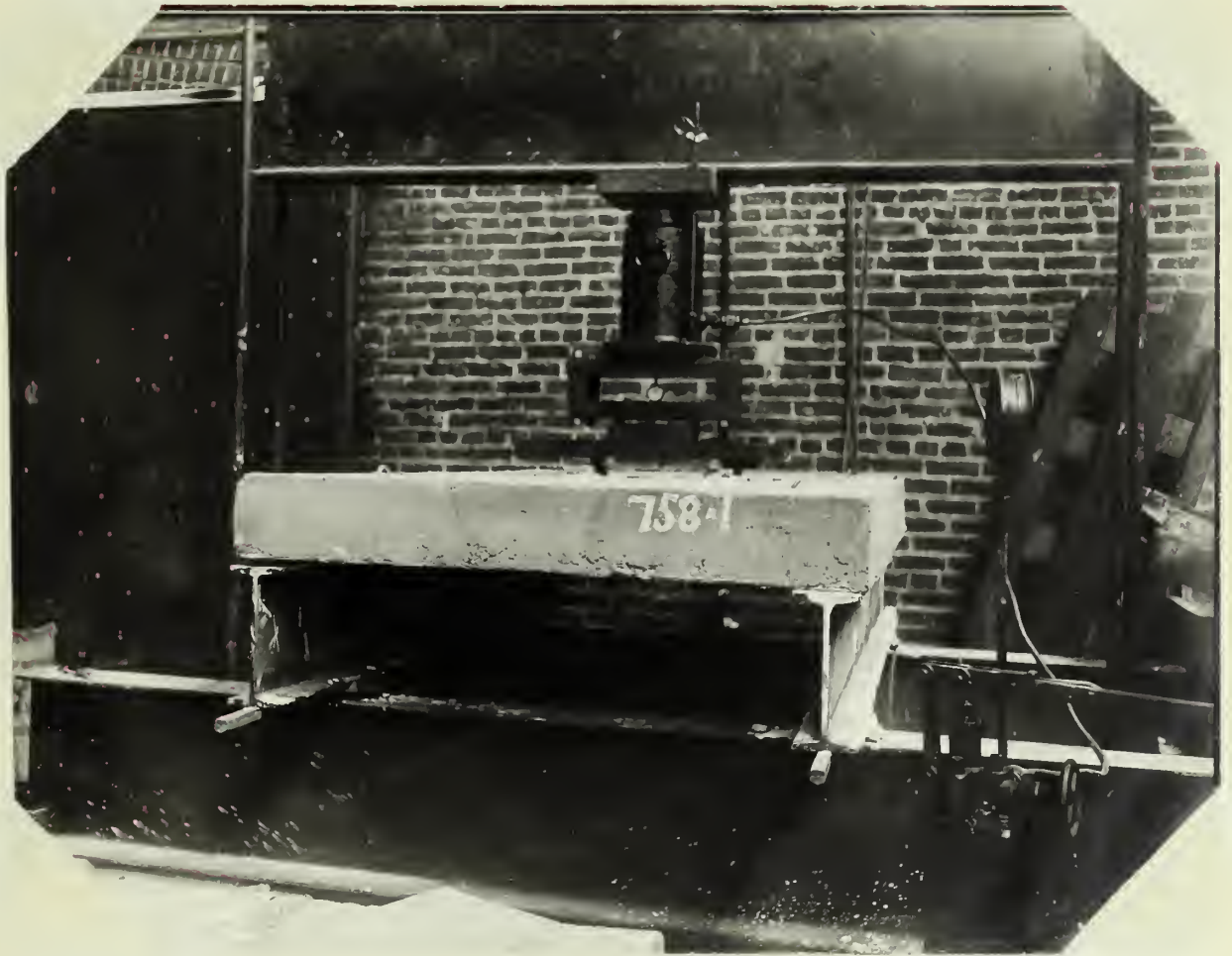
at an age of about 60 days, the exact ages being given in the summary sheet.

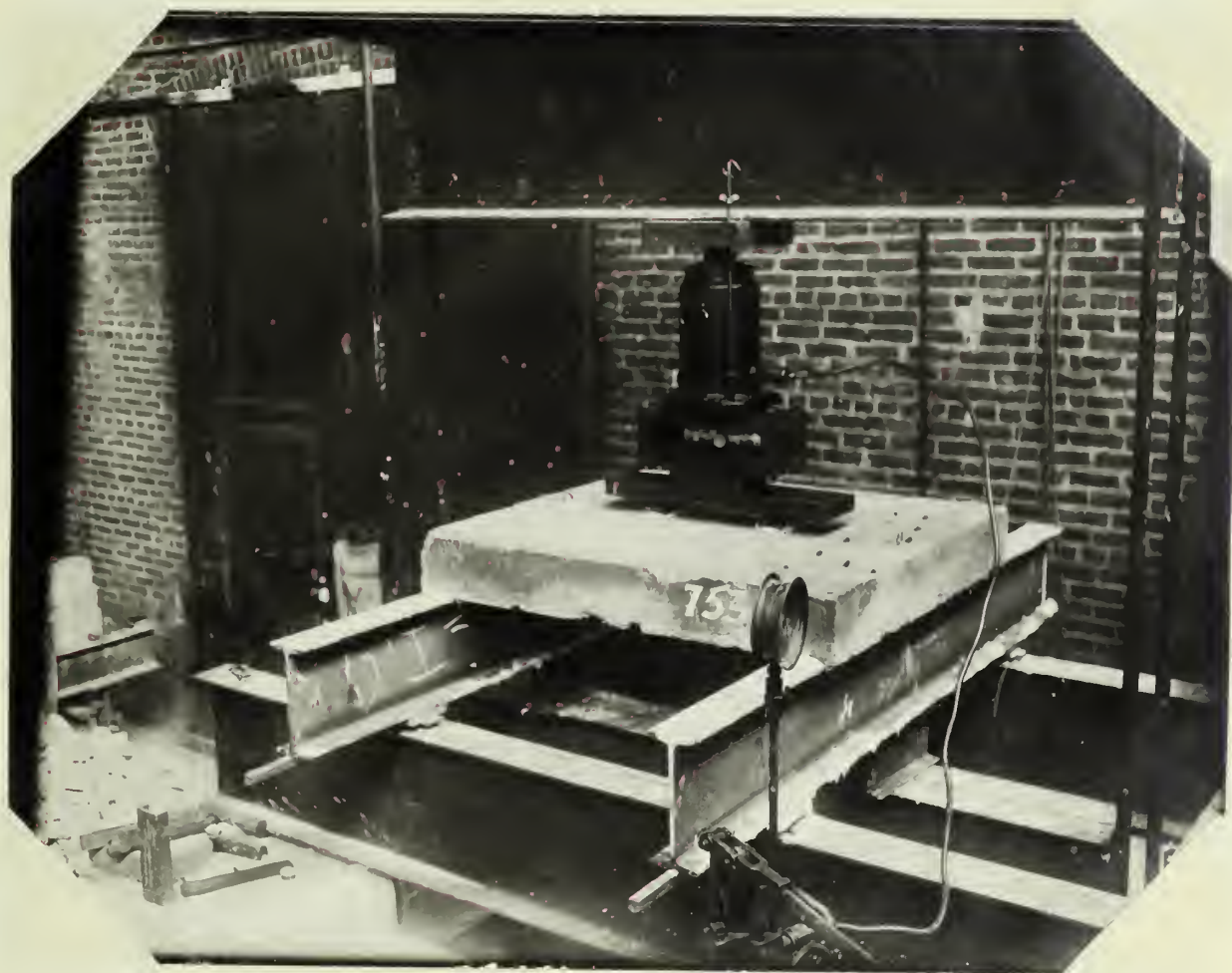
8. Method of Testing.- The beams were tested in a machine designed by the Experiment Station staff for the purpose of testing floor slabs. It was so designed that readings may be taken underneath the slab with the observer standing in a natural position. The load was applied by means of a hydraulic jack. This jack rested on a dynamometer as shown in the photographs on pages 7 to 11. The dynamometer was tested up to 140,000 pounds in one of the Riehle testing machines, and a calibration curve was prepared having the deflections of the dynamometer plotted as ordinates, and the load on the machine as abscissae. The load for any deflection was taken from this calibration curve which is shown on page 11.

The load blocks were cast-iron bars three inches wide by one inch thick, cut off at different lengths corresponding with the different ratios of loaded width to the total width of the beam. They were imbedded in plaster of paris the same as were the supporting I-Beams on which the beam rested. This was to insure an even bearing on the beam.

The first beams that were tested were supported by I-Beams as shown in Fig. 1 page 12. This method of support was thought to allow too great a deflection in the 12in. I-Beams, for the wider beams, so the method shown in Fig. 2 , page 12 was adopted. The load was usually applied in about four increments. This necessitated much larger increments than have ordinarily been used in test of reinforced concrete beams, but





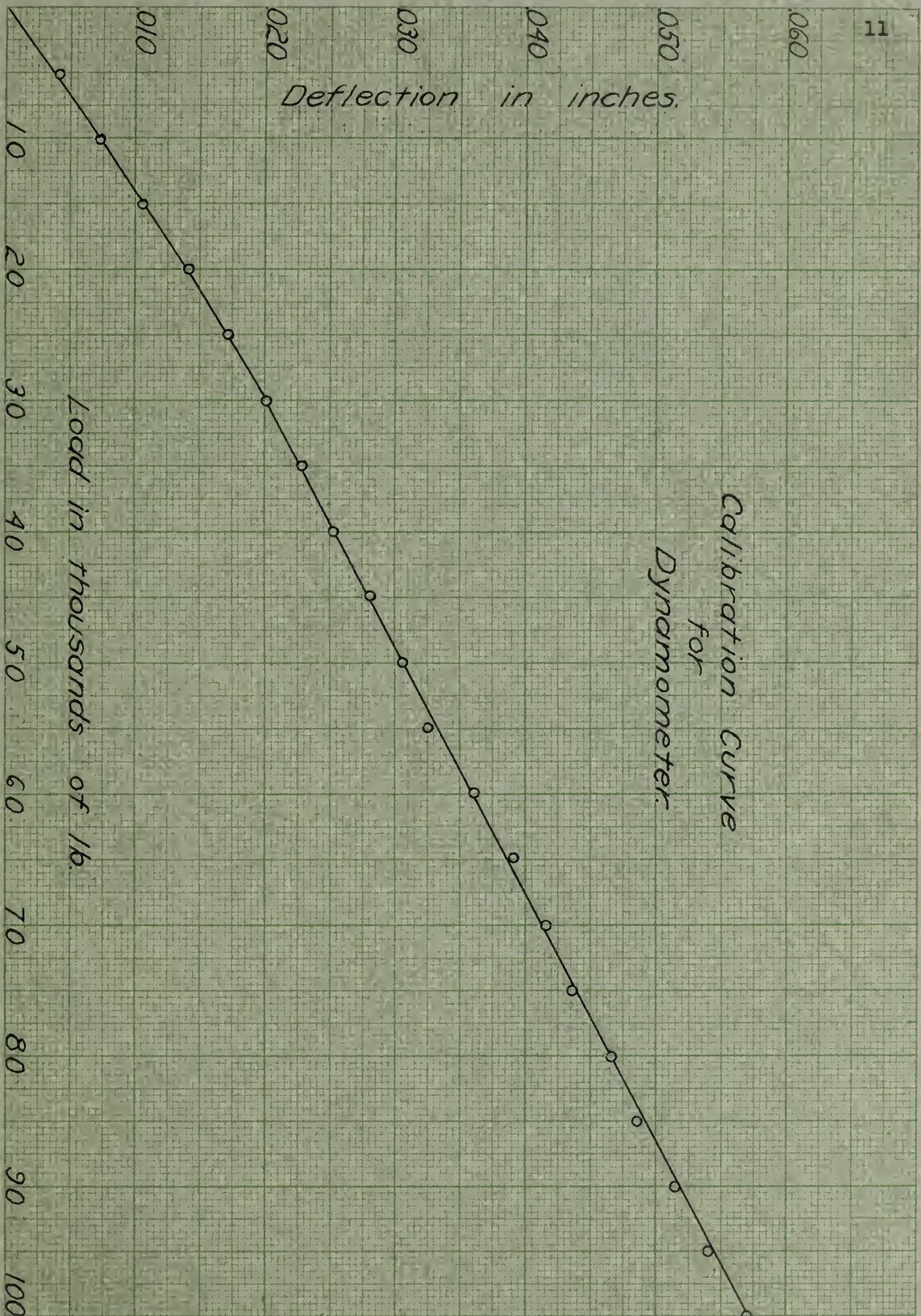




Calibration Curve
for
Dynamometer.

Deflection in inches.

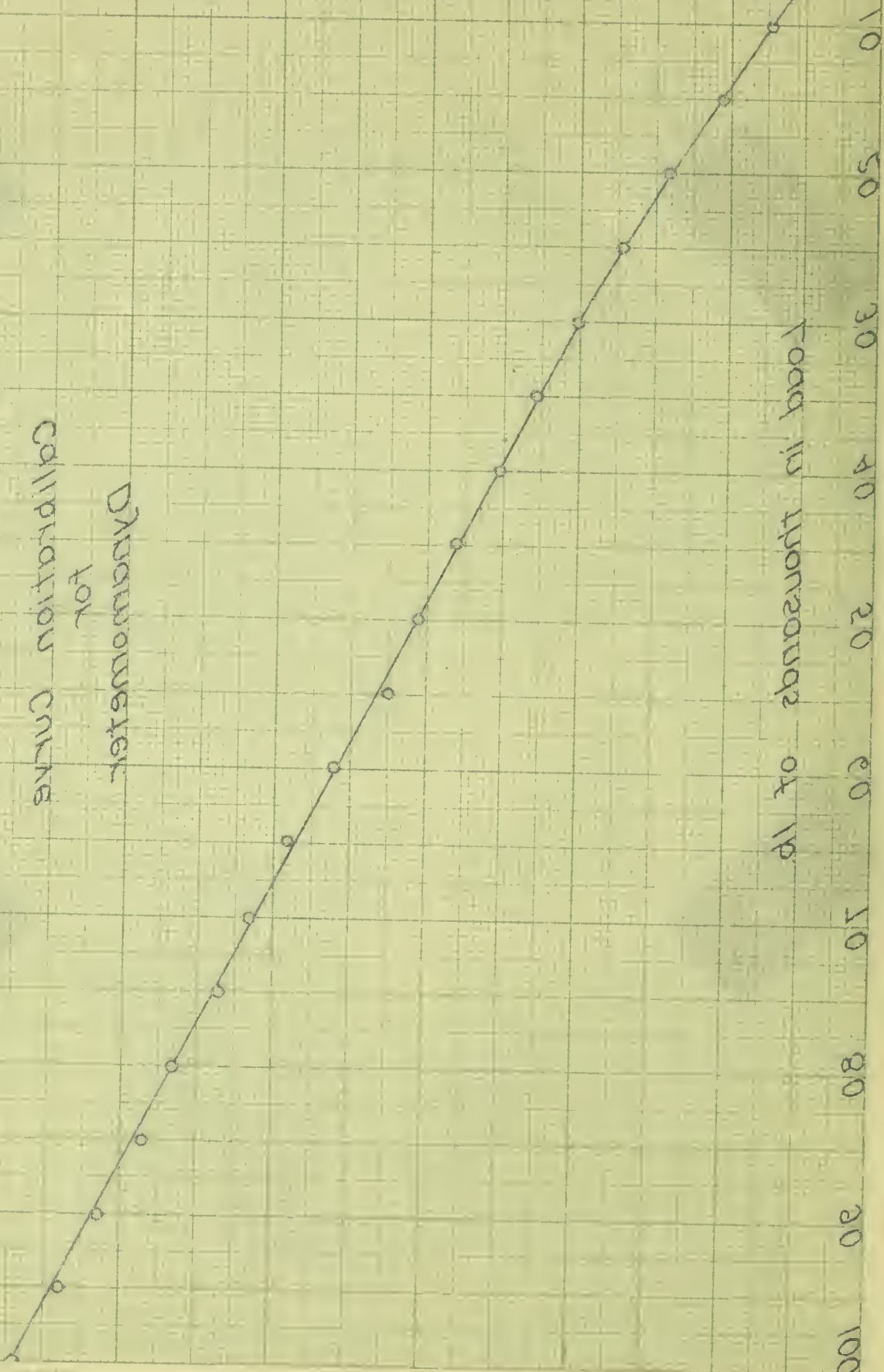
Load in thousands of lb.



Dynamometer
for
Calibration Curve

Deflection in inches

Load in thousands of lb



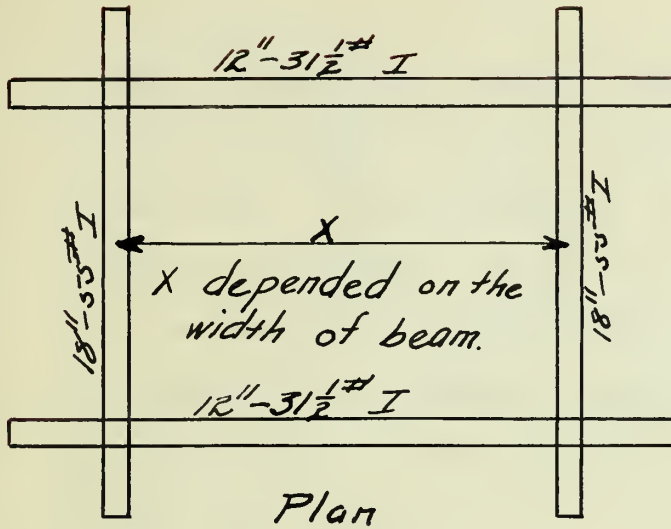


Fig. 1

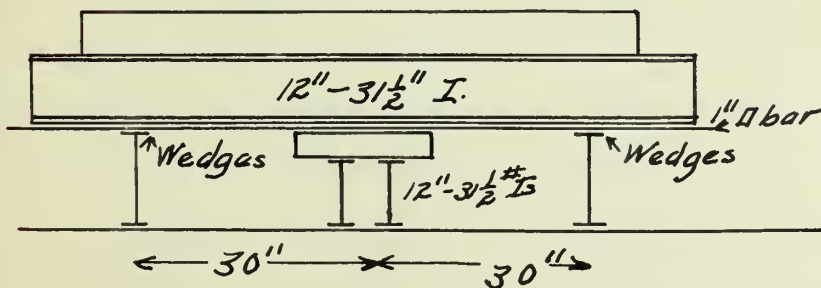
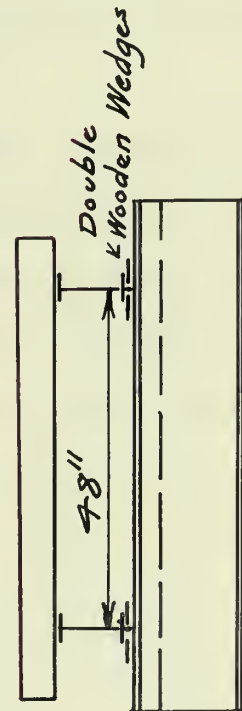
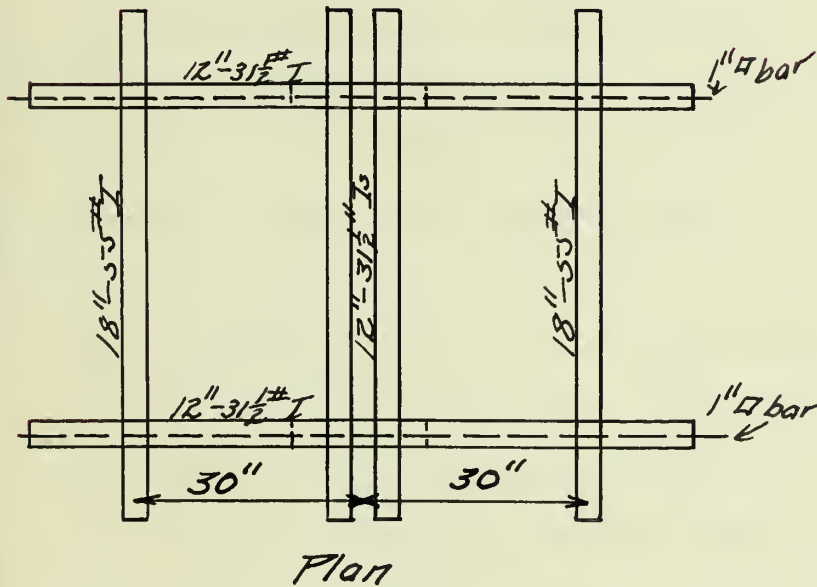
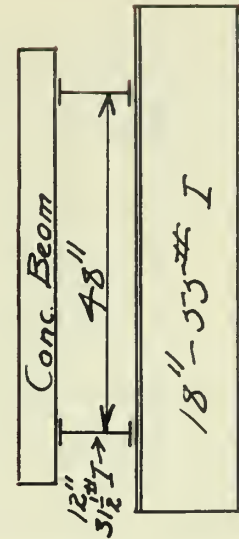


Fig. 2.

owing to the great length of time required to take a complete set of readings, it was necessary to reduce the number of increments. These increments varied, depending on the relative changes in stresses, and the indications of failure. They were smaller near the ultimate load than at the beginning, in order to determine the primary cause of failure, if possible. Since more emphasis was placed on the distribution of stress at a given load, than on the load stress relations the impracticability of applying the load in smaller increments does not seriously affect the value of the results.

The deformations of the steel were measured by the Berry extensometer, the principles of which are shown in Fig. 3. The arm (a-b) is hinged at (b) and the ratio of the distance (a-b) to the distance (b-c) is five, so that a movement of .001 inches of the dial, corresponds to an actual deformation in the steel of only .0002 inches or a stress of 1000 lb. per sq. in. if the gauge length is six inches and the modulus of elasticity of the steel is 30,000,000. The leg (d-e) is movable and can be varied from six inch gauge lengths to eleven inch gauge lengths. The amount of movement of the lever arm at (a) was measured by the dial. In order to use this instrument it was necessary to chisel out holes in the concrete to the steel, and then to drill holes in the steel about $\frac{3}{32}$ inches deep and $\frac{3}{64}$ inches in diameter, and adjust the instruments to these holes which were as nearly six inches apart as possible. The accuracy of the readings depends to a considerable extent on the skill of the operator and the smoothness of the holes.

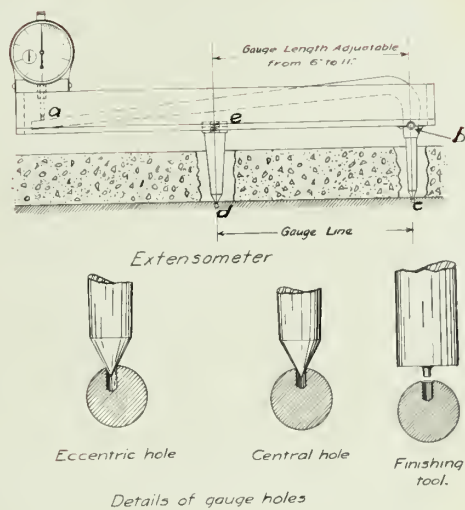


Fig. 3

No	Width (Inches)	Reinforcement						Date			Age of Test Days	Measured Stress in Steel					Calculated Stress in Long Steel			
		Longitud.			Transv.			Made Tested				Longitudinal			Transv.					
		%	No. Rods	Dia. Rods	%	No. Rods	Dia. Rods	Mo.	Da.	Yr.		Mo.	Da.	Yr.	Edge	Center		Av.	End	Cent.
750.1	24	1.07	7	$\frac{3}{8}$	0	0	0	11	4	11	6	12	63	42,000*	42,000*	41,500*	—	—	57,600	
751.1	"	"	14	"	"	"	"	"	28	"	2	9	"	73	34,500	32,000	33,200	—	—	38,200
752.1	"	"	"	"	"	"	"	"	"	"	"	6	"	70	29,400	33,800	31,600	—	—	30,200
.R	"	1.56	15	$\frac{7}{16}$	"	"	"	12	2	"	"	10	"	70	25,000	22,000	23,500	—	—	27,100
753.1	48	1.57	29	"	"	"	"	11	10	"	1	12	"	63	10,000	20,000	15,000	—	—	15,750
.R	"	"	"	"	"	"	"	"	22	"	2	2	"	72	16,000	20,000	18,000	—	—	15,700
754.1	"	"	"	"	.23	4	$\frac{3}{8}$	"	10	"	1	13	"	64	13,000	26,000	19,500	15,000	39,000	18,500
.R	"	"	"	"	"	"	"	"	25	"	2	6	"	74	16,000	36,000	26,000	28,000	42,000	21,000
755.1	"	"	"	"	.46	8	"	10	26	"	1	5	"	71	22,000	40,000	31,000	42,000*	42,000*	27,800
.R	"	"	22	$\frac{1}{2}$	"	"	"	12	6	"	2	17	"	73	21,000	26,000	23,500	42,000*	42,000*	21,600
756.1	72	1.50	33	"	.23	4	"	11	1	"	1	2	"	62	10,000	35,000	22,500	42,000	42,000*	16,900
.R	"	"	"	"	"	"	"	12	7	"	2	23	"	78	7,000	27,000	17,000	42,000*	42,000*	13,300
757.1	"	"	"	"	.78	10	$\frac{7}{16}$	11	18	"	1	10	"	62	14,000	28,000	21,000	42,000*	42,000*	12,000
.R	"	"	"	"	.75	13	$\frac{3}{8}$	12	9	"	2	24	"	77	10,000	23,000	16,500	30,000	42,000*	21,300
758.1	96	"	44	"	.23	4	"	11	22	"	"	2	"	72	4,000	20,000	12,000	42,000*	42,000*	12,000
.R	"	"	"	"	"	"	"	"	27	"	"	7	"	72	10,000	42,000*	21,500	42,000*	42,000*	11,100
759.1	36	1.02	20	$\frac{3}{8}$	.78	10	$\frac{7}{16}$	"	1	"	1	6	"	66	40,000	40,000	40,000	14,000	42,000	41,600
.R	"	"	"	"	.75	13	$\frac{3}{8}$	"	28	"	2	9	"	73	42,000*	42,000*	42,000*	—	—	35,200
760.1	"	"	"	"	.46	8	"	"	4	"	1	8	"	65	42,000*	42,000*	42,000*	18,000	22,000	42,700
.R	"	"	"	"	"	"	"	12	5	"	2	16	"	73	42,000	42,000	42,000	—	—	42,000
761.1	"	"	"	"	.23	4	"	11	22	"	1	20	"	59	30,000	30,000	30,000	23,000	32,000	27,700
.R	"	"	"	"	"	"	"	12	5	"	2	23	"	80	41,000	38,000	39,000	—	—	33,400
762.1	"	"	"	"	0	0	0	11	25	"	"	3	"	70	24,000	26,000	25,000	—	—	27,600
.R	"	"	"	"	"	"	"	12	5	"	"	17	"	74	34,000	30,000	32,000	—	—	25,600
763.1	48	1.04	"	$\frac{7}{16}$	"	"	"	10	26	"	1	2	"	68	12,000	42,000	27,000	—	—	16,600
.R	"	1.09	16	$\frac{1}{2}$	"	"	"	12	6	"	2	17	"	73	17,000	20,000	18,500	—	—	21,200
764.1	"	1.04	20	$\frac{7}{16}$	.78	10	$\frac{7}{16}$	11	18	"	1	15	"	58	35,000	24,000	29,500	36,000	34,000	34,700
.R	"	"	"	"	.75	13	$\frac{3}{8}$	12	2	"	2	10	"	70	37,000	34,000	35,500	20,000	40,000	34,400
765.1	72	"	23	$\frac{1}{2}$	.0	0	0	"	9	"	"	24	"	79	7,000	19,000	13,000	—	—	11,400
.R	"	"	"	"	"	"	"	"	5	"	"	17	"	74	8,000	20,000	14,000	—	—	14,400
766.1	"	"	"	"	.75	13	$\frac{3}{8}$	11	29	"	"	10	"	73	18,000	40,000	29,000	28,000	42,000*	28,700
.R	"	"	"	"	"	"	"	12	8	"	"	24	"	78	18,000	30,000	24,000	34,000	40,000	21,800
767.1	96	1.02	39	$\frac{7}{16}$	.78	10	$\frac{7}{16}$	11	24	"	"	5	"	73	6,000	32,000	19,000	42,000	42,000*	19,200
.R	"	"	30	$\frac{1}{2}$	.75	13	$\frac{3}{8}$	12	4	"	"	12	"	70	10,000	38,000	24,000	36,000	42,000*	19,900
768.1	48	.84	22	$\frac{3}{8}$	0	0	0	10	25	"	12	27	11	63	18,000	22,000	20,000	—	—	27,600
.R	"	"	"	"	.23	4	$\frac{3}{8}$	"	"	"	1	1	12	68	24,000	34,000	29,000	26,000	42,000*	30,200

Strength of Cubes lb. per sq. in	Bearing. lb. sq. in $\frac{W}{0.6b}$	Bond. lb. sq. in Max. Meas. S Bond A.	Vertical Shear $\sigma = \frac{V}{bjd}$	Efficiency $\frac{WQ}{P_1} = \frac{f}{f_1}$ 742.1 750.1		Manner of Failure	Load = gauge + 2000 lbs. for app.	No. 17 of beam
3120	970	148	116	1.29	1.00	T ₁	14000	750.1
2300	2530	234	153	.85	.66	S & B ₁	37000	751.1
2300	1440*	230	177	.67	.52	S & B ₁	41500	752.1
2470	2590	128	159	.61	.47	S	37300	.2
2035	1470	116	89	.35	.27	S	42500	753.1
2320	1460	116	88	.35	.27	S	42000	.2
1625	1740	157	105	.41	.32	S	50000	754.1
2610	1980	210	120	.48	.37	S	57000	.2
2310	2330	277	141	.55	.43	S & B ₁	67000	755.1
1825	2030	132	122	.48	.37	B _t	58300	.2
2290	1580	178	94	.37	.29	S	68000	756.1
1995	1340	137	74	.30	.23	S	53500	.2
	1770	143	106	.40	.32	B ₁	76500	757.1
2530	1900	117	114	.45	.35	B ₁ & B ₂	82000	.2
2130	1110	102	67	.27	.21	S	64000	758.1
2310	1030	214	63	.24	.19	S	59500	.2
2290	2790	272	159	.93	.72	B ₁	58000	759.1
2300	2270	286	135	.79	.61	B ₁ & D	49000	.2
3120	2760	286	163	.95	.74	B ₁	52500	760.1
2275	2710	286	161	.94	.73	B ₁ & D	58500	.2
2320	1790	204	106	.62	.48	B ₁ & B ₂	38600	761.1
2275	2160	279	128	.75	.58	B ₁	46500	.2
2610	1780	177	106	.62	.48	S	38500	762.1
2275	1650	232	98	.44	.34	S	35600	.2
2310	1100	291	65	.37	.29	S	31600	763.1
1825	1430	101	83	.48	.37	S	40300	.2
	2300	204	136	.77	.60	B ₁ & B ₂	66000	764.1
2470	2280	216	135	.77	.60	B ₁ & D	65300	.2
1670	740	97	44	.26	.20	S	32000	765.1
1970	930	101	56	.32	.25	S	40500	.2
2795	1930	202	111	.65	.50	B ₁	80700	766.1
1860	1430	152	85	.49	.38	B ₁	61500	.2
2475	1240	186	74	.43	.33	B ₁	71500	767.1
2740	1280	221	76	.44	.34	B ₁	73800	.2
2430	1420	178	87	.62	.48	S	43000	768.1
2430	1630	275	95	.67	.52	S	47000	.2



III EXPERIMENTAL DATA AND DISCUSSION

The original data obtained in these tests were recorded in notebooks kept by the Experiment Station and are too voluminous to be copied in this thesis. The results of individual tests are given in the form of a summary, in tables, and in curves plotted from reduced data.

The summary sheets on pages 16 and 17 give the ultimate loads, the manner of failure, the efficiencies as compared with the standard beam, the vertical shear, (v) in lb. per sq. in. the bond stress, the bearing of the load blocks on the beam, the calculated stress and the measured stress.

The stresses in the summary sheet that are marked with an asterisk (*) are to indicate that the steel went beyond the elastic limit, and that the true stresses were probably greater than these, but were taken as 42,000 lb. sq. in. as this was about the elastic limit of the steel.

10. Efficiency.- The efficiency of a beam has been defined as the ratio of the load carried, to the load it ought to carry in order to develop the full strength of all the longitudinal steel. The efficiencies of the beams in this series are seen to be low, but this is partly explained by the fact that the standard beam seems to have been exceptionally strong in comparison with the standard of 1911, and judging from the high calculated stress that is shown. Just why the calculated stress of the standard beam should differ so much from the measured stress, while all others agree fairly well, can not be explained. Even though the steel was stressed beyond the elastic limit, the deformation was measured and it did not indicate as high a stress as the calculated stress. The equat-

Efficiency Curves.

 $L = 1.0\%$

Depth = 6"

Span = 48"

Efficiency.

 $\circ = T = 0\%$ $\times = T = 23\%$ $\Delta = T = 46\%$ $\bullet = T = 78\%$ $T = 78\%$ $T = 23\%$ $T = 0\%$

Ratio of Width to Span.

0 0.5 1.0 1.5 2.0 2.5

 $L = 1.0\%$

Depth = 6"

Span = 48"

Efficiency.

Efficiency.

8

36" Width

48" Width

72" Width

96" Width

% Transverse Reinforcement

0 .2 .4 .6 .8 1.0

Efficiency Curves

Span = 48"
Depth = 6"
L = 10%

○ = T = 0%
x = T = 23%
△ = T = 78%
● = T = 78%

T = 0%
T = 23%
T = 78%

Efficiency

Ratio of Width to Span

0 0.2 0.5 1.0 2.0

Span = 48"
Depth = 6"
L = 10%

36" Width
48" Width
75" Width
82" Width

Efficiency

% Transverse Reinforcement

0 5 10 15 20

ion for the efficiency is derived in E.J.Schell's thesis page 18. The diagrams on page 20 of this thesis show the efficiencies of the various beams. The curves at the top of the same page show how the efficiency varies with the ratio of width to span, the longitudinal reinforcement being reduced to the same basis. The curves at the bottom of the page show the way in which the efficiency varies with the transverse reinforcement.

11. Shearing Stresses.- The vertical shearing stress shown in the summary sheet is the average for any cross section of the beam between the load and the support. It is likely that this is less than the shearing stress between the load and the support on a central longitudinal strip.

12. Bond Stresses.- The bond stresses are obtained by dividing the maximum measured stress in the rods by the bond area of that rod. In a bent up rod the bond area required should be sufficient to resist the stress due to the moment, in addition to the diagonal tensile stress carried by the rods.

13. Bearing Stresses.- The bearing blocks were three inches wide and one-tenth the width of the beam, with the exception of beam No. 752.1, which was two-tenths, making the total bearing area in sq. in. equal to $2 \times 3 \times .1 \times b = 0.6b$ where b is given in inches. The bearing values in many cases are shown to be higher than the compressive strength of cubes of the same quality of concrete. Just what effect these high bearing values had on the manner of failure is not known.

14. Ultimate Loads.- For a given beam the recorded load is 2000 pounds greater than the load indicated by the dynamometer. This is to correct for the weight of the dynamometer,

jack, and the 24 inch I-Beam above the jack.

15. Manner of Failure.- The manner of failure is designated by symbols as follows;

T_1 indicates a failure by tension in the longitudinal steel.

S indicates a slab failure. In this thesis any tension failure of either the concrete or steel in the transverse direction, which results in a longitudinal crack in the center, has been designated as a slab failure.

B_1 and B_t indicate failures due to slipping of the longitudinal and transverse rods respectively.

D indicates failure by diagonal tension. Tension failures in steel and diagonal tension failures are discussed in bulletins No. 4 and 14 of the Experiment Station.

All the beams of this series failed either as a slab or because of insufficient bond. The only exceptions are beams No. 764.2, 760.2 and 759.2. These failed by bond and diagonal tension. In all cases except beams No. 759.1 and 764.1 the stresses were higher in the transverse steel than in the longitudinal steel at failure. This seems to indicate that these two beams were the only ones over-reinforced in the transverse direction. They failed by bond but had high stresses in the longitudinal steel. Since the experimental determination of the proper amount of transverse reinforcement depends largely on the results of tests in which failure is caused by tension in either the longitudinal or the transverse reinforcement, it is unfortunate that so many of these beams failed in bond.

16. Load Stress Diagram.- The data obtained in regard to stresses are plotted on pages 32 to 111. The diagrams having loads as ordinates and stresses as abscissae show the loads and the corresponding stresses for various bars of the beam. Stresses were not measured in all the bars. Only enough bars were measured to show the general distribution of stress across the beams.

The diagrams having stresses as ordinates and width of beam as abscissae show the general distribution of stress. Two loads were chosen at which the stresses in the longitudinal steel were plotted and three loads for stresses in the transverse steel. In each case the stresses were plotted for such a load as stressed the steel, first, to about 15,000 lb. per. sq. in., and second, to about 40,000 lb. per. sq. in. The third load for the transverse steel was that which stressed the longitudinal steel to about 15,000 lb. per. sq. in. These curves show that the narrower the beam the less the amount of transverse reinforcement required. They indicate also, that the stress in the transverse steel increases at a more rapid rate than does the load, whereas this is not true of the stresses in the longitudinal steel.

17. Deflection Diagrams.- The diagrams from page 112 to 116 show the curling of the beams in the transverse direction, and the deflection of the supporting I-Beams. The increased deflection of the supporting I-Beams at the maximum load indicate that at failure the load is all concentrated in the central portion of the beam. An exact mathematical solution, showing why the beams curl up from the supports near the outer edges, seems to be an impossibility, but the following considerations

may throw some light on the subject. The radius of curvature of a beam, having a constant moment of inertia varies inversely as the bending moment, and as the bending moment in the transverse direction is greatest at the center due to the load being concentrated there, the radius of curvature is the least at that point. The stiffness of concrete tends to keep all sections in the same position with respect to each other, consequently the tendency due to this sharp radius of curvature at the center is to lift the ends of the transverse sections from the supports, thus forming cantilever beams of the outer transverse sections.

18. Theory:- The fact that wide beams fail by tension in a transverse direction is the evidence that there must be transverse flexure, since there are no forces applied transversely. The only way in which load can be carried to the member when considered as a transverse beam, is through shear between adjacent longitudinal strips.

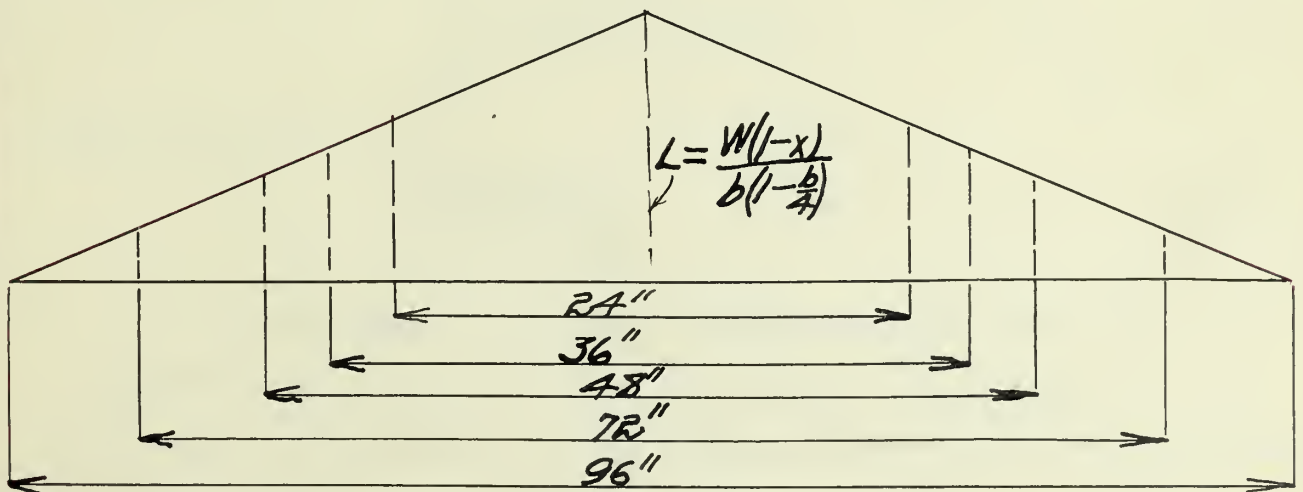
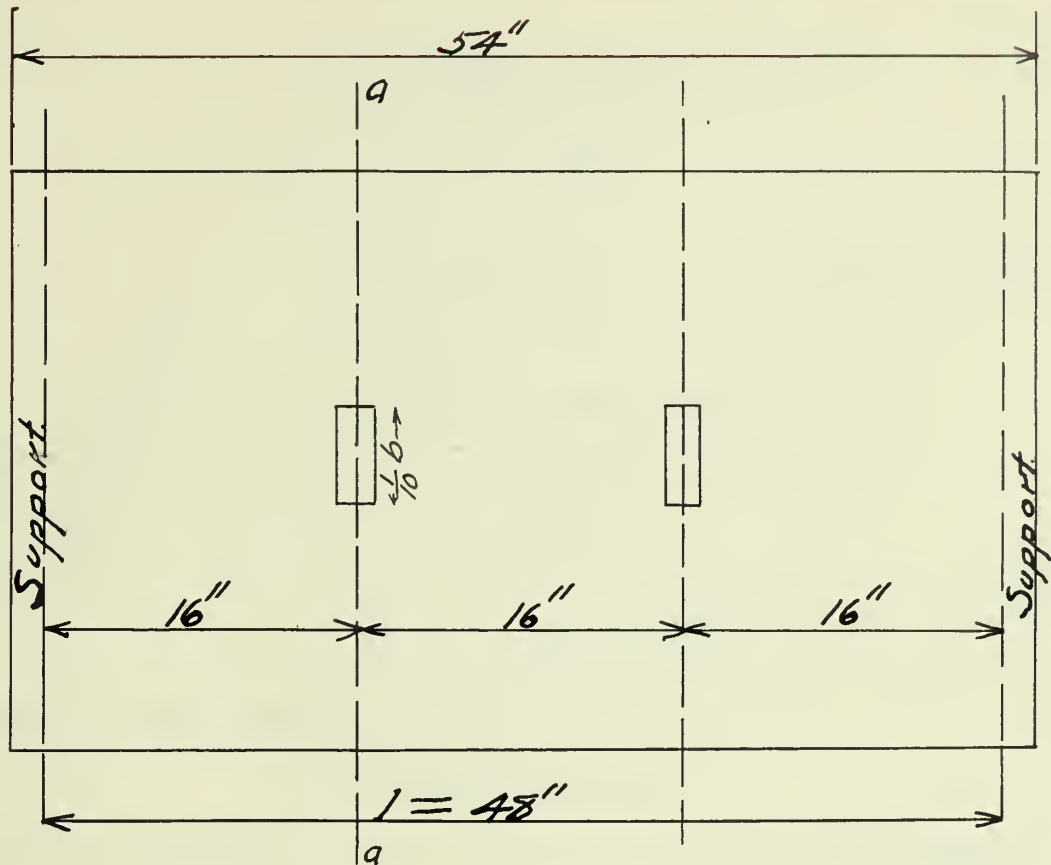
The data of the tests show that the stresses in the longitudinal steel fall off gradually, from a maximum at the center to practically zero at the edge for a beam 96 inches wide, and that the amount of transverse reinforcement required varies with varying ratios of widths to length, increasing as the ratio of width to length increases. In order to determine the proper ratio of transverse reinforcement to the longitudinal reinforcement, the following equation has been derived, based on the assumption, (1), that the shear between any two adjacent strips is approximately proportional to the difference between the steel stresses in the two strips, (2), that for the same condition of loading, the load carried by any longitudinal strip of a beam, is proportional to the stresses developed in the longitudinal steel in that strip, and (3), that the load is not distributed over a width greater than twice the span.

According to the above assumptions, the load curve is a straight line, as shown on page 26.

Let $l =$ span.

$K =$ intensity of load at center.

$x =$ any distance out from the center.



Load Curve. Sec. through (a-a)

L = intensity of load at distance x .

W = load on beam.

b = width.

d = effective depth of longitudinal sections.

f = stress in longitudinal steel.

A = area of longitudinal steel.

jd = arm of resisting couple.

M = bending moment.

p = per. cent of longitudinal reinforcement.

M_t , A_t , j_t , d_t , f_t , d_t , and p_t corresponding values in the transverse sections.

V_t = transverse shear.

Then the intensity of the load at any point at a distance x is

$$L = \frac{K(1-x)}{1}$$

When $x = \frac{b}{2}$ or $1/2$ the width of the beam the area under the curve must equal the total load W or

$$\left[\frac{K + K \left(\frac{1 - \frac{b}{2}}{1} \right)}{2} \right] \frac{b}{2} = \frac{W}{2}$$

Solving for K

$$K = \frac{Wl}{b \left(1 - \frac{b}{4} \right)}$$

This means that under the assumptions used for load distribution the stresses produced at the center due to a load " W " would be equivalent to the stress produced by a load uniformly distributed over the entire width equal to

$$\left[\frac{Wl}{b \left(1 - \frac{b}{4} \right)} \right] x b = \frac{Wl}{\left(1 - \frac{b}{4} \right)}$$

$$L = \frac{W(1-x)}{b \left(1 - \frac{b}{4} \right)}$$

$$V_t = \int L dx = \int \left[\frac{W(1-x)}{b \left(1 - \frac{b}{4} \right)} \right] dx = \frac{W}{b \left(1 - \frac{b}{4} \right)} \left(1x - \frac{x^2}{2} \right) + C$$

Determining the constant of integration by the condition that $V_t = 0$ when $x = \frac{b}{2}$.

$$V_t = \frac{W}{b \left(1 - \frac{b}{4} \right)} \left(1x - \frac{x^2}{2} \right) - \frac{W}{2}$$

$$\int V_t dx = M_t = \int \left[\frac{W}{b \left(1 - \frac{b}{4} \right)} \left(1x - \frac{x^2}{2} \right) - \frac{W}{2} \right] dx = \frac{W}{b \left(1 - \frac{b}{4} \right)} \left(\frac{1}{2} x^2 - \frac{x^3}{6} \right) - \frac{Wx}{2} + C_1$$

$$M_t = 0 \text{ when } x = \frac{b}{2}$$

$$M_t = \frac{W}{b \left(1 - \frac{b}{4} \right)} \left(\frac{1}{2} x^2 - \frac{x^3}{6} \right) - \frac{Wx}{2} + \frac{Wb}{4} - \left(\frac{Wb}{1 - \frac{b}{4}} \right) \left(\frac{1}{8} - \frac{b}{48} \right)$$

M_t is a maximum when $x = 0$

$$\text{Max. } M_t = \frac{Wb}{8 \left(1 - \frac{b}{4} \right)} \left(1 - \frac{b}{3} \right)$$

$$\text{Also } M_t = f_t A_t j_t d_t$$

For economical design f_t at the center should equal f for a load W .

The data of these tests seem to indicate as a fair

assumption that "f" at the center due to a concentrated load "W" is the same as would be caused by a load of intensity equal to $\frac{Wl}{b(1 - \frac{b}{4})}$ (as derived on page 28), distributed across the full

width of the beam at the one-third points of the span.

This would equal a total load of $\frac{Wl}{b(1 - \frac{b}{4})} \times b$ or $\frac{Wl}{(1 - \frac{b}{4})}$

$$M = K_1 Pl \quad \text{and} \quad P = \frac{Wl}{(1 - \frac{b}{4})}$$

K_1 coefficient depending on loading.

Substitute for P its value above

$$M = \frac{K_1 Wl^2}{(1 - \frac{b}{4})}$$

$$f = \frac{M}{Ajd} = \frac{K_1 Wl^2}{(1 - \frac{b}{4}) Ajd}$$

$$\text{Now} \quad A_t = \frac{M_t}{f_t j_t d_t}$$

Put $f_t = f$ and substitute value of M_t .

$$\text{Then } A_t = \frac{\frac{Wb(1 - \frac{b}{3})}{8(1 - \frac{b}{4})}}{\left(\frac{K_1 Wl^2}{(1 - \frac{b}{4}) Ajd} \right) j_t d_t} = \frac{Ab(1 - \frac{b}{3})}{8K_1 l^2} \times \frac{j_d}{j_t d_t}$$

$j_t = \text{practically } j.$

$$A_t = \frac{Ab \left(1 - \frac{b}{3}\right)}{8 K_1 l^2} \times \frac{d}{d_t}$$

$$A_t = p_t l d_t \quad A = p b d$$

$$p_t l d_t = \frac{p b^2 d \left(1 - \frac{b}{3}\right)}{8 K_1 l^2} \times \frac{d}{d_t}$$

$$\frac{p_t}{p} = \frac{b^2 \left(1 - \frac{b}{3}\right)}{8 K_1 l^2} \times \left(\frac{d}{d_t}\right)^2$$

$$\text{Put } b = K_2 l$$

$$\text{Then } \frac{p_t}{p} = \frac{K_2^2 l^2 \left(1 - \frac{K_2 l}{3}\right)}{8 K_1 l^3} \times \left(\frac{d}{d_t}\right)^2$$

$$= \frac{K_2^2 \left(1 - \frac{1}{3} K_2\right)}{8 K_1} \times \left(\frac{d}{d_t}\right)^2$$

This formula is stated in general terms, but since all the beams of this series were of the same span and had a minimum ratio of depth to span of 1/16, further test on beams of different spans and depths will be necessary in order to determine its adaptability to other conditions.

19. Summary.- The following statements are to be taken not as final conclusions, but as a partial interpretation of the results of these tests.

1. The amount of transverse reinforcement required for narrow beams is very small. It seems that for beams having a width of one-half the span, or less, no transverse reinforcement is necessary.

2. The amount of transverse reinforcement required, increases as the width of beam increases.

3. The stresses in the longitudinal steel under a concentrated load are greater than for the same load extending over the full width of the beam.

4. The stresses in the longitudinal steel fall off gradually from the center towards the outer edges, reaching zero at a width equal to about twice the span.

5. The stresses in the longitudinal and transverse steel increase at different rates, the transverse stresses increasing more rapidly near the ultimate load.

6. In the continuation of this investigation, it is necessary to make other provisions than were made in the beams of this series to prevent bond failures.

Since the tests are limited in their scope as stated on page 30, any application of these interpretations to other conditions should not be made without considering these limitations.

Beam No. 7501

Rods No. Size %

Long 7 3/8 107

Trans. 0 0 0

Width 24"

Max. Load 14,000 lb.

Beam No. 7511

Rods No. Size %

Long. 14 3/8 107

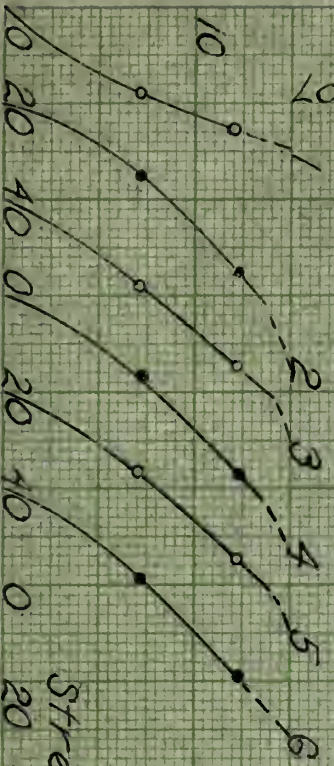
Trans. 0 0 0

Width 24"

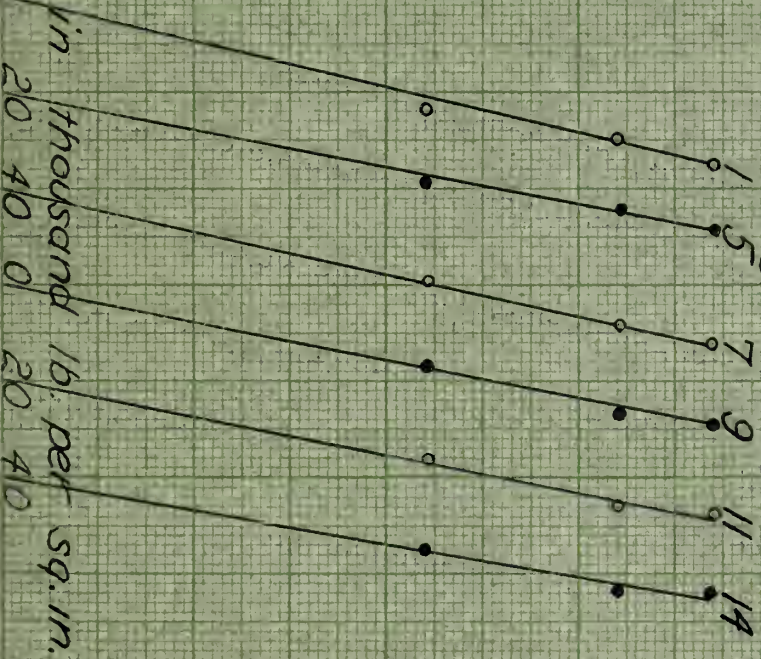
Max. Load 37,000 lb.

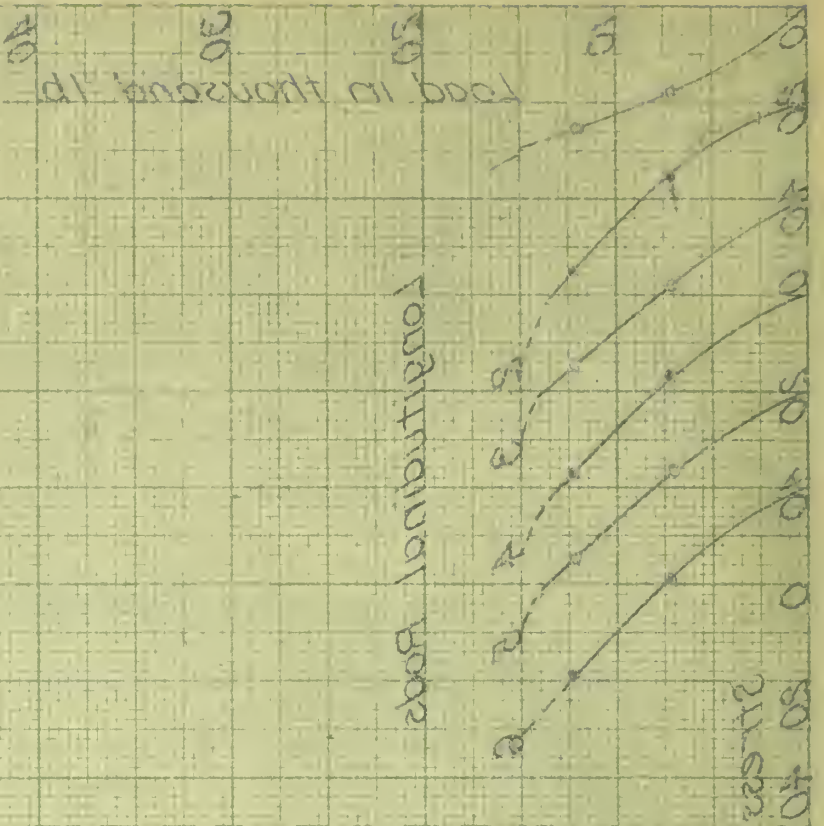
Load in thousand lb.

Longitudinal Rods

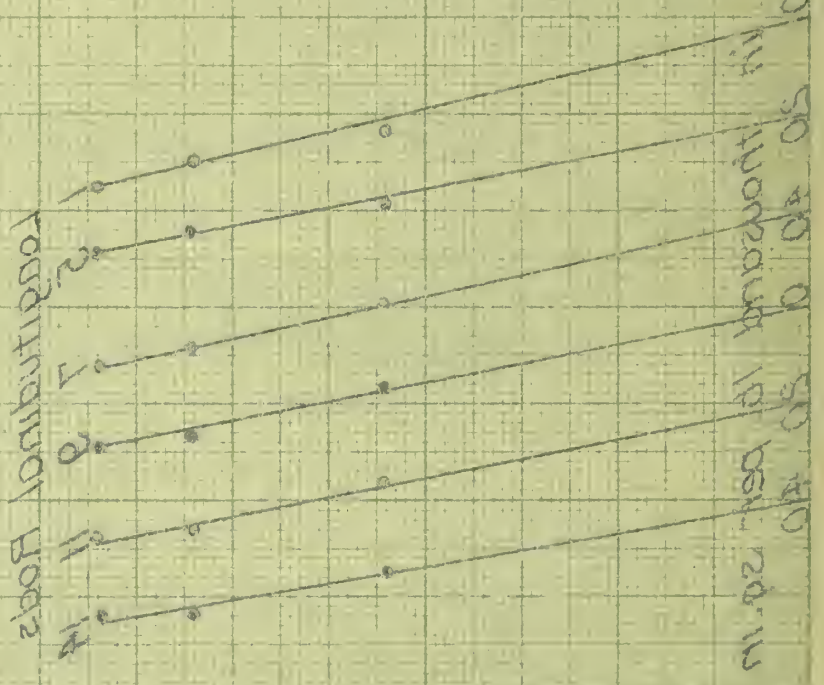


Longitudinal Rods





Max Load 14,000 lb
 Width 54"
 Area 0 0 0
 Load 1 3/8 101
 Load No. 215 %
 Beam No. 12001



Max Load 35,000 lb
 Width 54"
 Area 0 0 0
 Load 1 3/8 101
 Load No. 215 %
 Beam No. 12011

Beam No. 750.1

Rods No. Size %

Long. 7 3/8" 107

Trans. 0 0 0

Width 24"

Max. Load 14,000 lb.

Beam No. 751.1

Rods No. Size %

Long. 14 3/8" 107

Trans. 0 0 0

Width 24"

Max. Load 37,000 lb.

Beam No. 752.1

Rods No. Size %

Long. 14 3/8" 107

Trans. 0 0 0

Width 24"

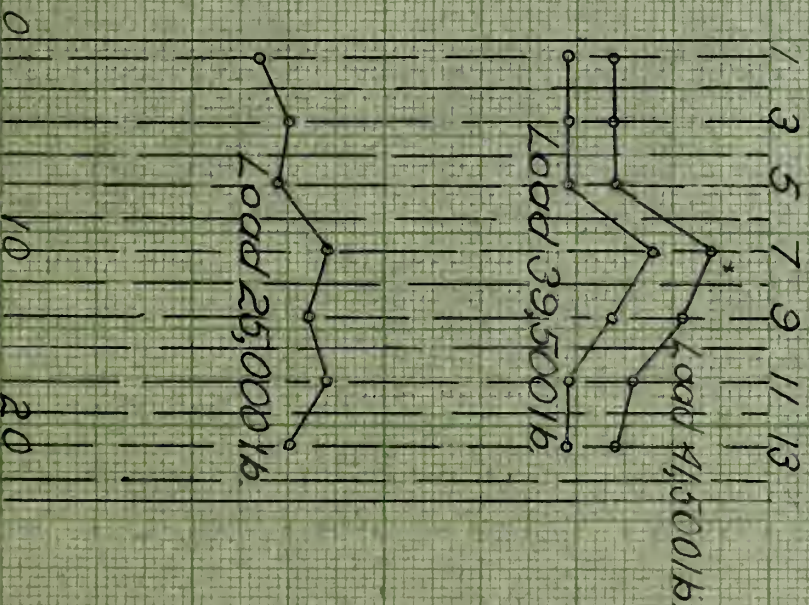
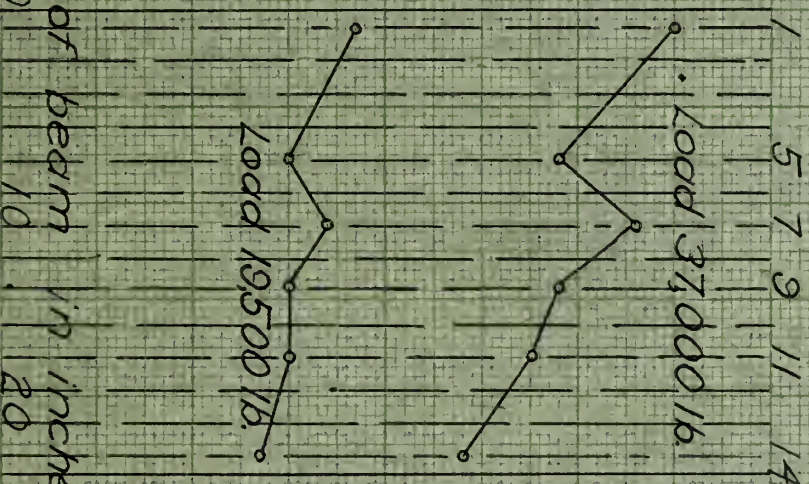
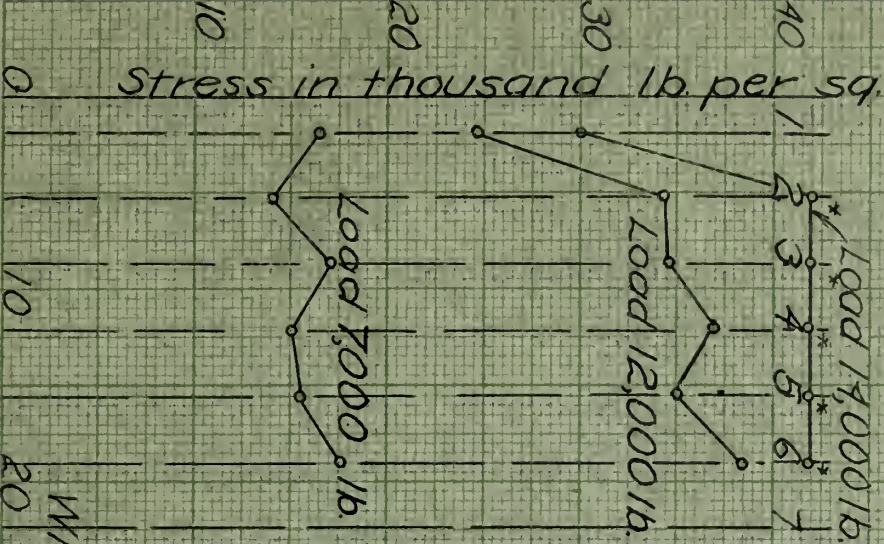
Max. Load 41,500 lb.

Longitudinal Rods

Longitudinal Rods

Longitudinal Rods

Stress in thousand lb. per sq. in.



Beam No. 752.1

Rods No. Size %

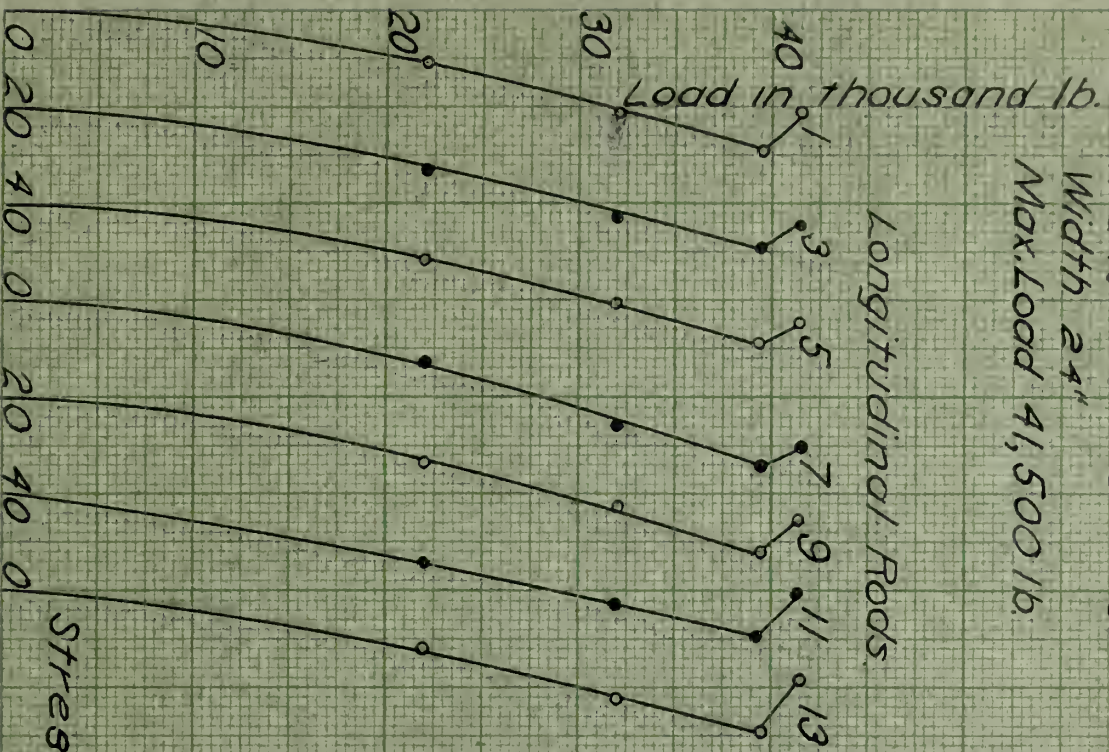
Long. 14 3/8" 107

Trans. 0 0 0

Width 24"

Max. Load 41,500 lb.

Longitudinal Rods.



Beam No. 752.2

Rods No. Size %

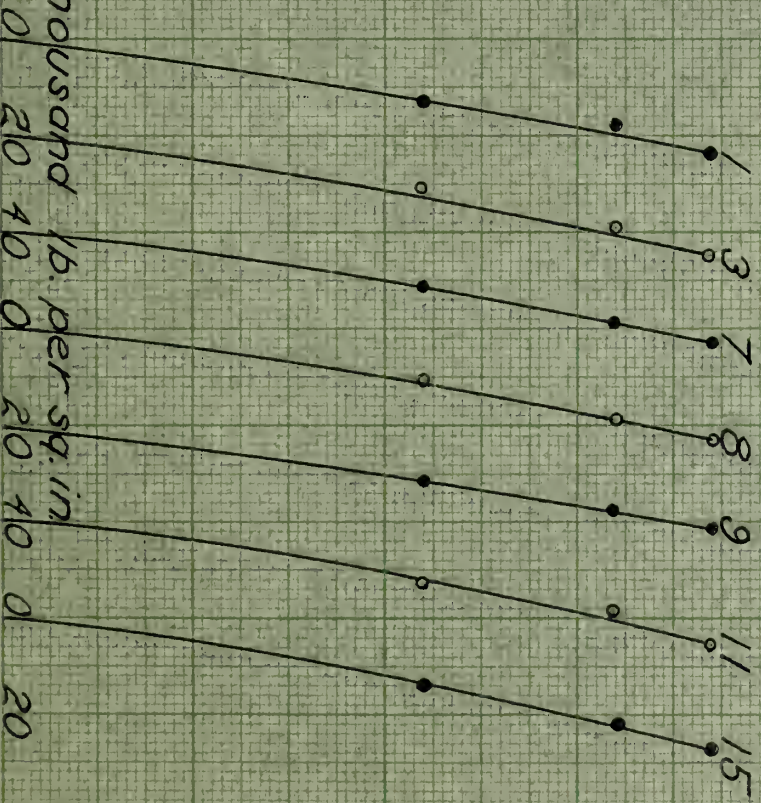
Long. 15 7/16" 156

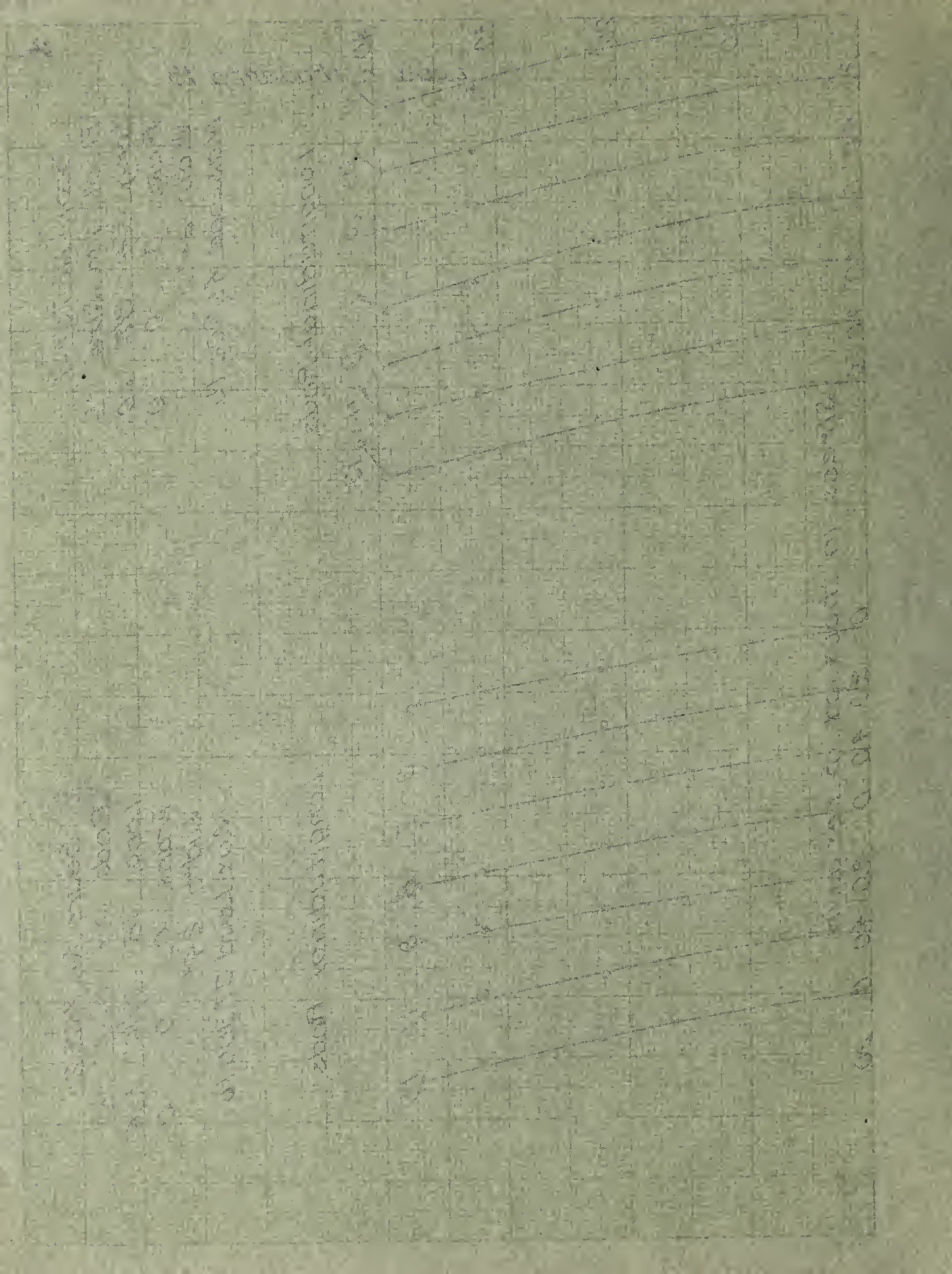
Trans. 0 0 0

Width 24"

Max. Load 37,300 lb.

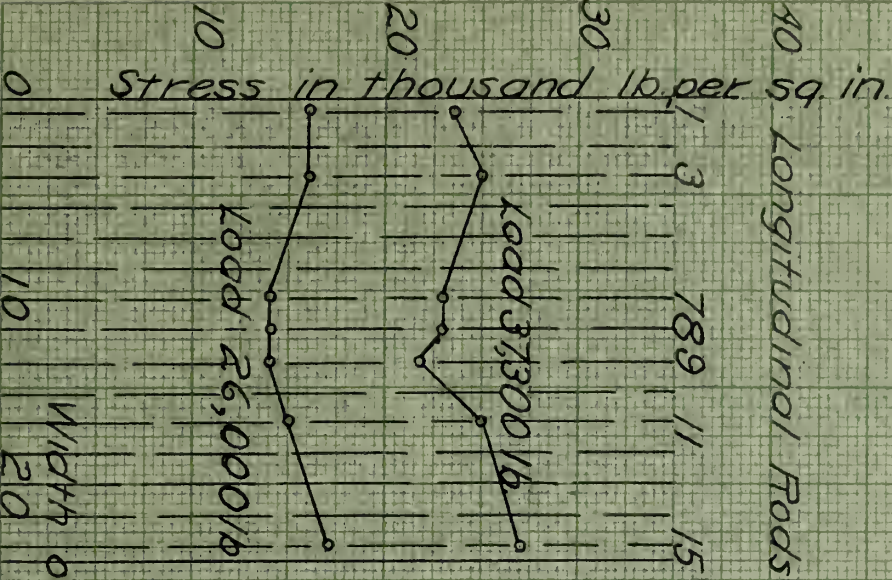
Longitudinal Rods.





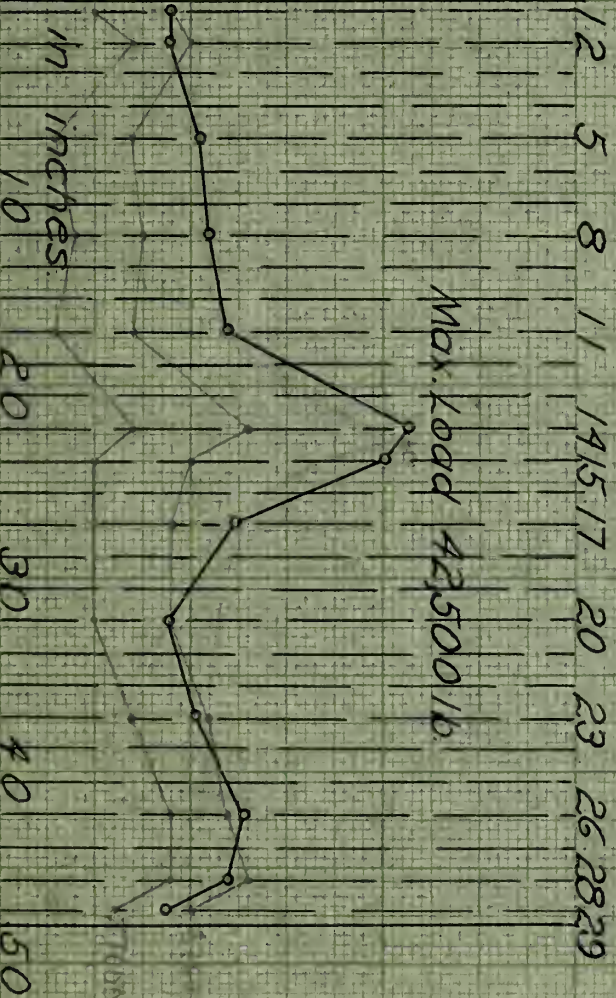
Beam No 7522
 Rods No. Size %
 Long. 15 7/16" 1.56
 Trans. 0 0 0
 Width 24"
 Max Load 37,300 lb.

40 Longitudinal Rods



Beam No 7531
 Rods No. Size %
 Long. 29 7/16" 1.51
 Trans. 0 0 0
 Width 48"
 Max Load 42,500 lb.

Longitudinal Rods



Beam No. 7531

Rods No. Size %

Long. 29 7/16" 1.51

Trans. 0 0 0

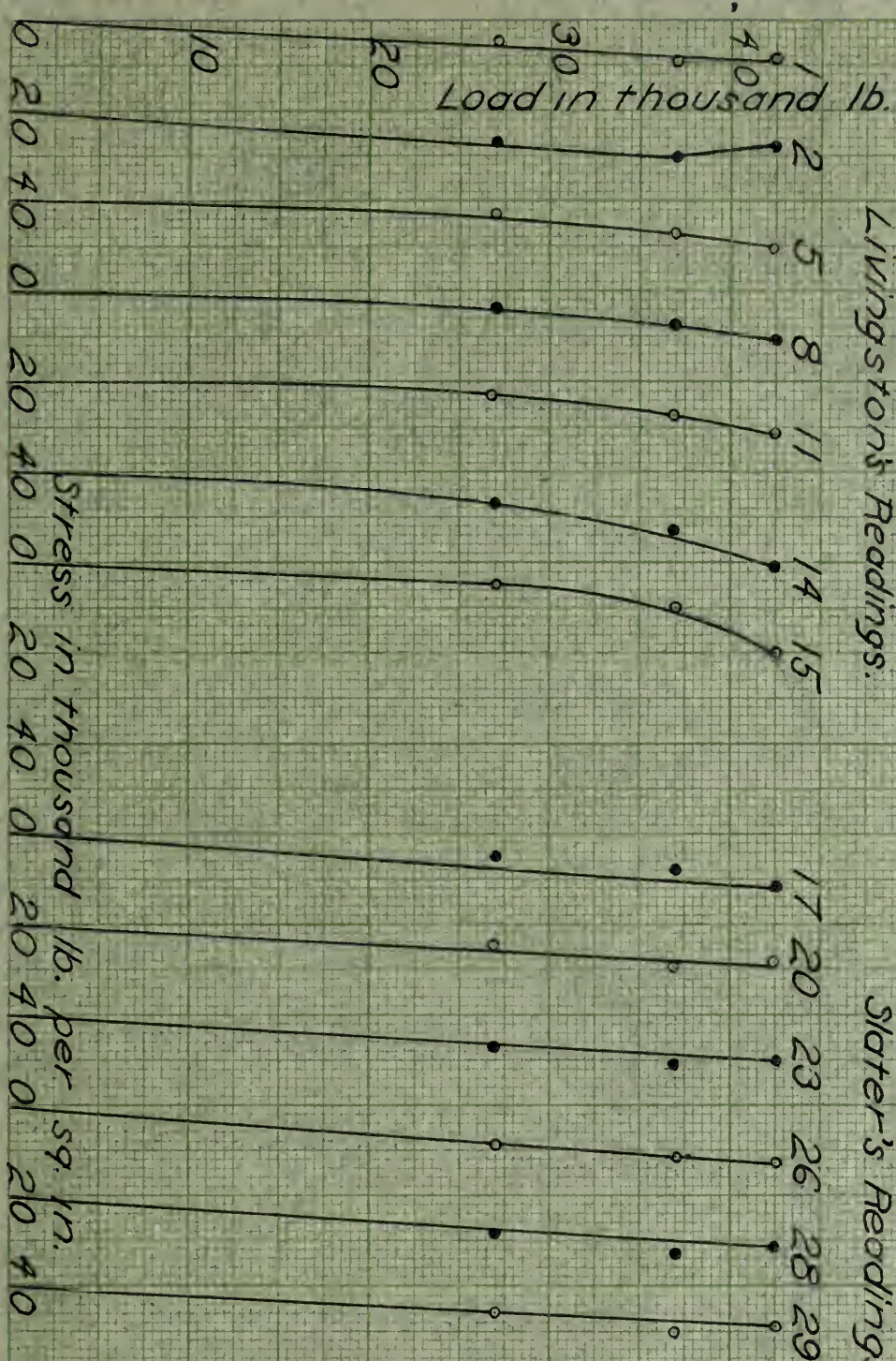
Width 48"

Max. Load 42,500 lb.

Livingston's Readings.

Longitudinal Rods.

Slater's Readings.



1905

[Faint handwritten notes at the bottom of the page]

... ..

1890

... ..

1940

1990

1890

[Faint handwritten notes at the bottom of the page]

1890

1940

1900

1. The first part of the document is a list of names and their corresponding numbers. The names are: "John", "Mary", "James", "Elizabeth", "Thomas", "Margaret", "William", "Ann", "Richard", "Sarah", "George", "Catherine", "Henry", "John", "Mary", "James", "Elizabeth", "Thomas", "Margaret", "William", "Ann", "Richard", "Sarah", "George", "Catherine", "Henry". The numbers are: "1", "2", "3", "4", "5", "6", "7", "8", "9", "10", "11", "12", "13", "14", "15", "16", "17", "18", "19", "20", "21", "22", "23", "24", "25", "26", "27", "28", "29", "30", "31", "32", "33", "34", "35", "36", "37", "38", "39", "40", "41", "42", "43", "44", "45", "46", "47", "48", "49", "50", "51", "52", "53", "54", "55", "56", "57", "58", "59", "60", "61", "62", "63", "64", "65", "66", "67", "68", "69", "70", "71", "72", "73", "74", "75", "76", "77", "78", "79", "80", "81", "82", "83", "84", "85", "86", "87", "88", "89", "90", "91", "92", "93", "94", "95", "96", "97", "98", "99", "100".

1944

1900

1. *Phragmites australis* (Cav.) Trin. ex Steud.
 2. *Scirpus americanus* L.
 3. *Scirpus setaceus* L.
 4. *Scirpus torreyana* (Cav.) Trin. ex Steud.
 5. *Scirpus torreyana* (Cav.) Trin. ex Steud.
 6. *Scirpus torreyana* (Cav.) Trin. ex Steud.
 7. *Scirpus torreyana* (Cav.) Trin. ex Steud.
 8. *Scirpus torreyana* (Cav.) Trin. ex Steud.
 9. *Scirpus torreyana* (Cav.) Trin. ex Steud.
 10. *Scirpus torreyana* (Cav.) Trin. ex Steud.

1. The first part of the document is a list of names and their corresponding addresses. The names are written in a cursive script, and the addresses are written in a more formal, printed script. The list is organized into two columns, with names on the left and addresses on the right.

... ..

1. The first part of the document is a list of names and their corresponding numbers, arranged in two columns. The names are written in a cursive script, and the numbers are written in a simple, bold font. The names are:

- 1. John A. Smith
- 2. James B. Jones
- 3. William C. Brown
- 4. Robert D. White
- 5. Thomas E. Green
- 6. Charles F. Black
- 7. Henry G. Gray
- 8. George H. White
- 9. Richard I. Black
- 10. Edward J. Gray
- 11. John K. White
- 12. William L. Black
- 13. Robert M. Gray
- 14. Thomas N. White
- 15. Charles O. Black
- 16. Henry P. Gray
- 17. George Q. White
- 18. Richard R. Black
- 19. Edward S. Gray
- 20. John T. White
- 21. William U. Black
- 22. Robert V. Gray
- 23. Thomas W. White
- 24. Charles X. Black
- 25. Henry Y. Gray
- 26. George Z. White
- 27. Richard AA. Black
- 28. Edward BB. Gray
- 29. John CC. White
- 30. William DD. Black
- 31. Robert EE. Gray
- 32. Thomas FF. White
- 33. Charles GG. Black
- 34. Henry HH. Gray
- 35. George II. White
- 36. Richard JJ. Black
- 37. Edward KK. Gray
- 38. John LL. White
- 39. William MM. Black
- 40. Robert NN. Gray
- 41. Thomas OO. White
- 42. Charles PP. Black
- 43. Henry QQ. Gray
- 44. George RR. White
- 45. Richard SS. Black
- 46. Edward TT. Gray
- 47. John UU. White
- 48. William VV. Black
- 49. Robert WW. Gray
- 50. Thomas XX. White
- 51. Charles YY. Black
- 52. Henry ZZ. Gray
- 53. George AAA. White
- 54. Richard BBB. Black
- 55. Edward CCC. Gray
- 56. John DDD. White
- 57. William EEE. Black
- 58. Robert FFF. Gray
- 59. Thomas GGG. White
- 60. Charles HHH. Black
- 61. Henry III. Gray
- 62. George KKK. White
- 63. Richard LLL. Black
- 64. Edward MMM. Gray
- 65. John NNN. White
- 66. William OOO. Black
- 67. Robert PPP. Gray
- 68. Thomas QQQ. White
- 69. Charles RRR. Black
- 70. Henry SSS. Gray
- 71. George TTT. White
- 72. Richard UUU. Black
- 73. Edward VVV. Gray
- 74. John WWW. White
- 75. William XXX. Black
- 76. Robert YYY. Gray
- 77. Thomas ZZZ. White
- 78. Charles AAAA. Black
- 79. Henry BBBB. Gray
- 80. George CCCC. White
- 81. Richard DDDD. Black
- 82. Edward EEEE. Gray
- 83. John FFFF. White
- 84. William GGGG. Black
- 85. Robert HHHH. Gray
- 86. Thomas IIII. White
- 87. Charles KKKK. Black
- 88. Henry LLLL. Gray
- 89. George MMMM. White
- 90. Richard NNNN. Black
- 91. Edward OOOO. Gray
- 92. John PPPP. White
- 93. William QQQQ. Black
- 94. Robert RRRR. Gray
- 95. Thomas SSSS. White
- 96. Charles TTTT. Black
- 97. Henry UUUU. Gray
- 98. George VVVV. White
- 99. Richard WWWW. Black
- 100. Edward XXXX. Gray
- 101. John YYYYY. White
- 102. William ZZZZ. Black
- 103. Robert AAAAA. Gray
- 104. Thomas BBBBB. White
- 105. Charles CCCC. Black
- 106. Henry DDDD. Gray
- 107. George EEEE. White
- 108. Richard FFFF. Black
- 109. Edward GGGG. Gray
- 110. John HHHH. White
- 111. William IIII. Black
- 112. Robert KKKK. Gray
- 113. Thomas LLLL. White
- 114. Charles MMMM. Black
- 115. Henry NNNN. Gray
- 116. George OOOO. White
- 117. Richard PPPP. Black
- 118. Edward QQQQ. Gray
- 119. John RRRR. White
- 120. William SSSS. Black
- 121. Robert TTTT. Gray
- 122. Thomas UUUU. White
- 123. Charles VVVV. Black
- 124. Henry WWWW. Gray
- 125. George XXXX. White
- 126. Richard YYYYY. Black
- 127. Edward ZZZZ. Gray
- 128. John AAAAA. White
- 129. William BBBBB. Black
- 130. Robert CCCC. Gray
- 131. Thomas DDDD. White
- 132. Charles EEEE. Black
- 133. Henry FFFF. Gray
- 134. George GGGG. White
- 135. Richard HHHH. Black
- 136. Edward IIII. Gray
- 137. John KKKK. White
- 138. William LLLL. Black
- 139. Robert MMMM. Gray
- 140. Thomas NNNN. White
- 141. Charles OOOO. Black
- 142. Henry PPPP. Gray
- 143. George QQQQ. White
- 144. Richard RRRR. Black
- 145. Edward SSSS. Gray
- 146. John TTTT. White
- 147. William UUUU. Black
- 148. Robert VVVV. Gray
- 149. Thomas WWWW. White
- 150. Charles XXXX. Black
- 151. Henry YYYYY. Gray
- 152. George ZZZZ. White
- 153. Richard AAAAA. Black
- 154. Edward BBBBB. Gray
- 155. John CCCC. White
- 156. William DDDD. Black
- 157. Robert EEEE. Gray
- 158. Thomas FFFF. White
- 159. Charles GGGG. Black
- 160. Henry HHHH. Gray
- 161. George IIII. White
- 162. Richard KKKK. Black
- 163. Edward LLLL. Gray
- 164. John MMMM. White
- 165. William NNNN. Black
- 166. Robert OOOO. Gray
- 167. Thomas PPPP. White
- 168. Charles QQQQ. Black
- 169. Henry RRRR. Gray
- 170. George SSSS. White
- 171. Richard TTTT. Black
- 172. Edward UUUU. Gray
- 173. John VVVV. White
- 174. William WWWW. Black
- 175. Robert XXXX. Gray
- 176. Thomas YYYYY. White
- 177. Charles ZZZZ. Black
- 178. Henry AAAAA. Gray
- 179. George BBBBB. White
- 180. Richard CCCC. Black
- 181. Edward DDDD. Gray
- 182. John EEEE. White
- 183. William FFFF. Black
- 184. Robert GGGG. Gray
- 185. Thomas HHHH. White
- 186. Charles IIII. Black
- 187. Henry KKKK. Gray
- 188. George LLLL. White
- 189. Richard MMMM. Black
- 190. Edward NNNN. Gray
- 191. John OOOO. White
- 192. William PPPP. Black
- 193. Robert QQQQ. Gray
- 194. Thomas RRRR. White
- 195. Charles SSSS. Black
- 196. Henry TTTT. Gray
- 197. George UUUU. White
- 198. Richard VVVV. Black
- 199. Edward WWWW. Gray
- 200. John XXXX. White
- 201. William YYYYY. Black
- 202. Robert ZZZZ. Gray
- 203. Thomas AAAAA. White
- 204. Charles BBBBB. Black
- 205. Henry CCCC. Gray
- 206. George DDDD. White
- 207. Richard EEEE. Black
- 208. Edward FFFF. Gray
- 209. John GGGG. White
- 210. William HHHH. Black
- 211. Robert IIII. Gray
- 212. Thomas KKKK. White
- 213. Charles LLLL. Black
- 214. Henry MMMM. Gray
- 215. George NNNN. White
- 216. Richard OOOO. Black
- 217. Edward PPPP. Gray
- 218. John QQQQ. White
- 219. William RRRR. Black
- 220. Robert SSSS. Gray
- 221. Thomas TTTT. White
- 222. Charles UUUU. Black
- 223. Henry VVVV. Gray
- 224. George WWWW. White
- 225. Richard XXXX. Black
- 226. Edward YYYYY. Gray
- 227. John ZZZZ. White
- 228. William AAAAA. Black
- 229. Robert BBBBB. Gray
- 230. Thomas CCCC. White
- 231. Charles DDDD. Black
- 232. Henry EEEE. Gray
- 233. George FFFF. White
- 234. Richard GGGG. Black
- 235. Edward HHHH. Gray
- 236. John IIII. White
- 237. William KKKK. Black
- 238. Robert LLLL. Gray
- 239. Thomas MMMM. White
- 240. Charles NNNN. Black
- 241. Henry OOOO. Gray
- 242. George PPPP. White
- 243. Richard QQQQ. Black
- 244. Edward RRRR. Gray
- 245. John SSSS. White
- 246. William TTTT. Black
- 247. Robert UUUU. Gray
- 248. Thomas VVVV. White
- 249. Charles WWWW. Black
- 250. Henry XXXX. Gray
- 251. George YYYYY. White
- 252. Richard ZZZZ. Black
- 253. Edward AAAAA. Gray
- 254. John BBBBB. White
- 255. William CCCC. Black
- 256. Robert DDDD. Gray
- 257. Thomas EEEE. White
- 258. Charles FFFF. Black
- 259. Henry GGGG. Gray
- 260. George HHHH. White
- 261. Richard IIII. Black
- 262. Edward KKKK. Gray
- 263. John LLLL. White
- 264. William MMMM. Black
- 265. Robert NNNN. Gray
- 266. Thomas OOOO. White
- 267. Charles PPPP. Black
- 268. Henry QQQQ. Gray
- 269. George RRRR. White
- 270. Richard SSSS. Black
- 271. Edward TTTT. Gray
- 272. John UUUU. White
- 273. William VVVV. Black
- 274. Robert WWWW. Gray</

1. The first part of the paper is devoted to the study of the properties of the function $f(x)$ defined by the equation

The first of these is the fact that the
 H^+ ions are not free in the solution,
 but are bound up in the form of
 H_2O^+ ions. This is due to the fact
 that the H^+ ions are attracted to
 the OH^- ions, and form a
 H_2O^+ ion. This ion is then
 attracted to the OH^- ions, and
 forms a H_2O^+ ion. This process
 continues until the solution is
 saturated with H_2O^+ ions.

Beam No. 753.2

Rods No. Size %

Long. 29 7/16" 1.51

Trans. 0 0 0

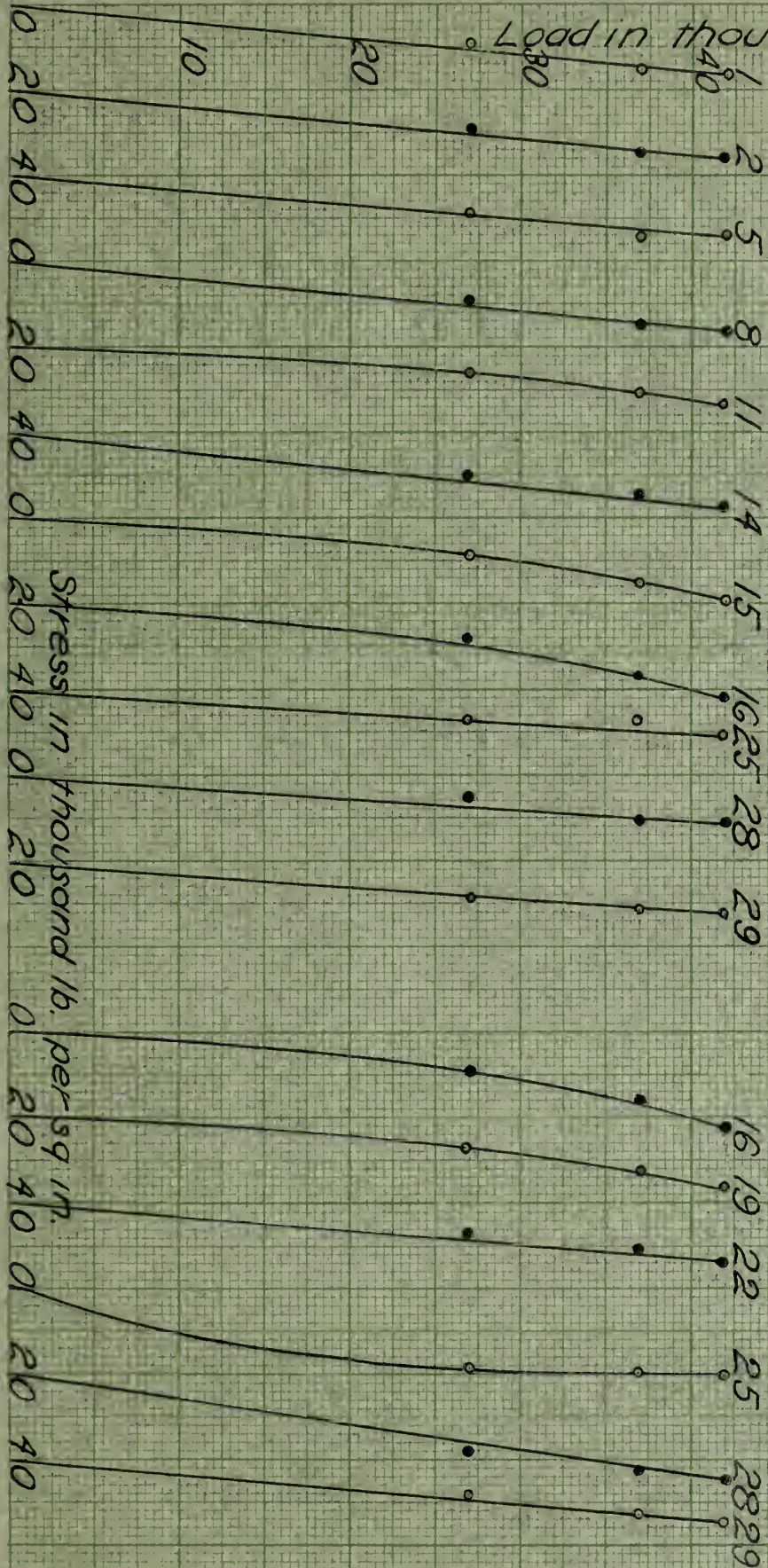
Width 48"

Max. Load 42,000 lb.

Slater's Readings.

Longitudinal Rods.

Ellis's Readings.

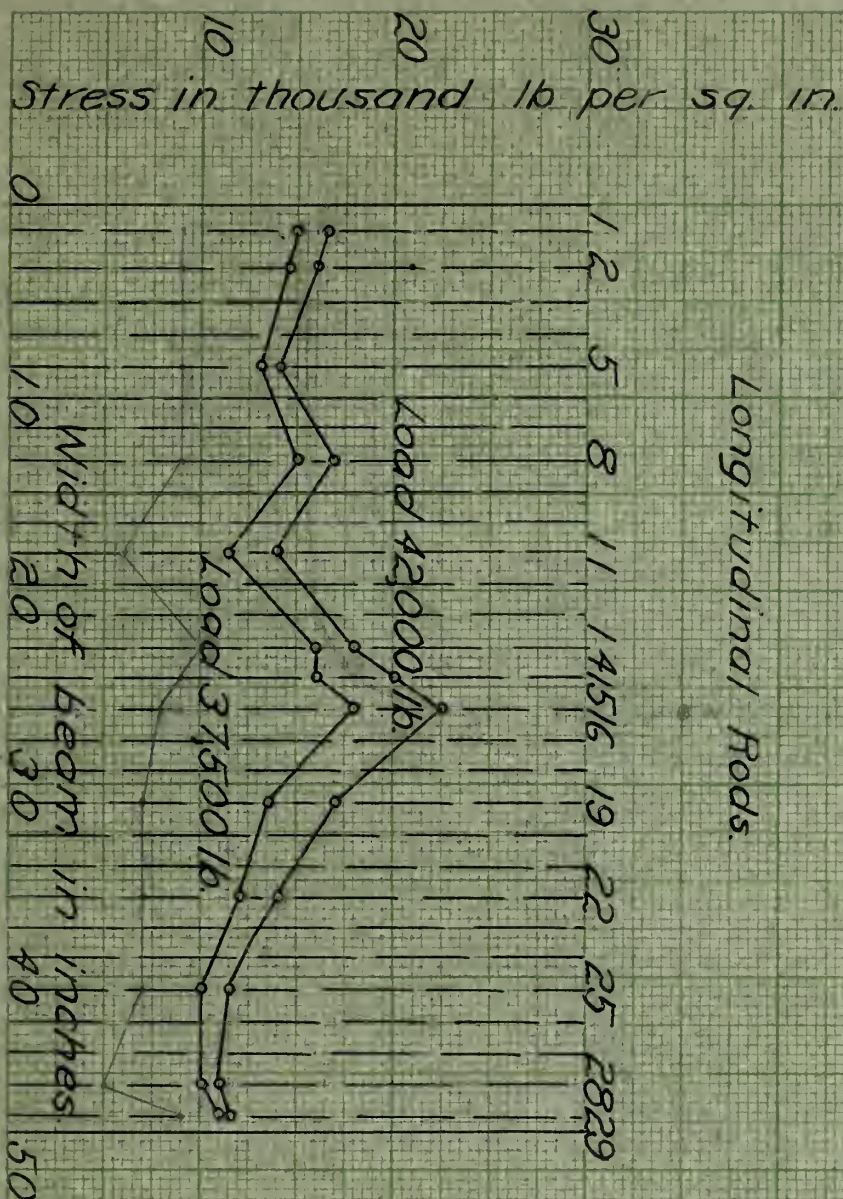


Stress in thousand lb. per sq in.

$\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$

Beam No 7532
 Rods No. Size %
 Long 29 7/16" 151
 Trans 0 0 0
 Width 48"
 Max. Load 42,000 lb

Longitudinal Rods.



Beam No. 7541

Rods No. Size %

Long 29 7/16" 1.51

Trans. 4 3/8" .23

Width 48"

Max. Load 50,000 lb.

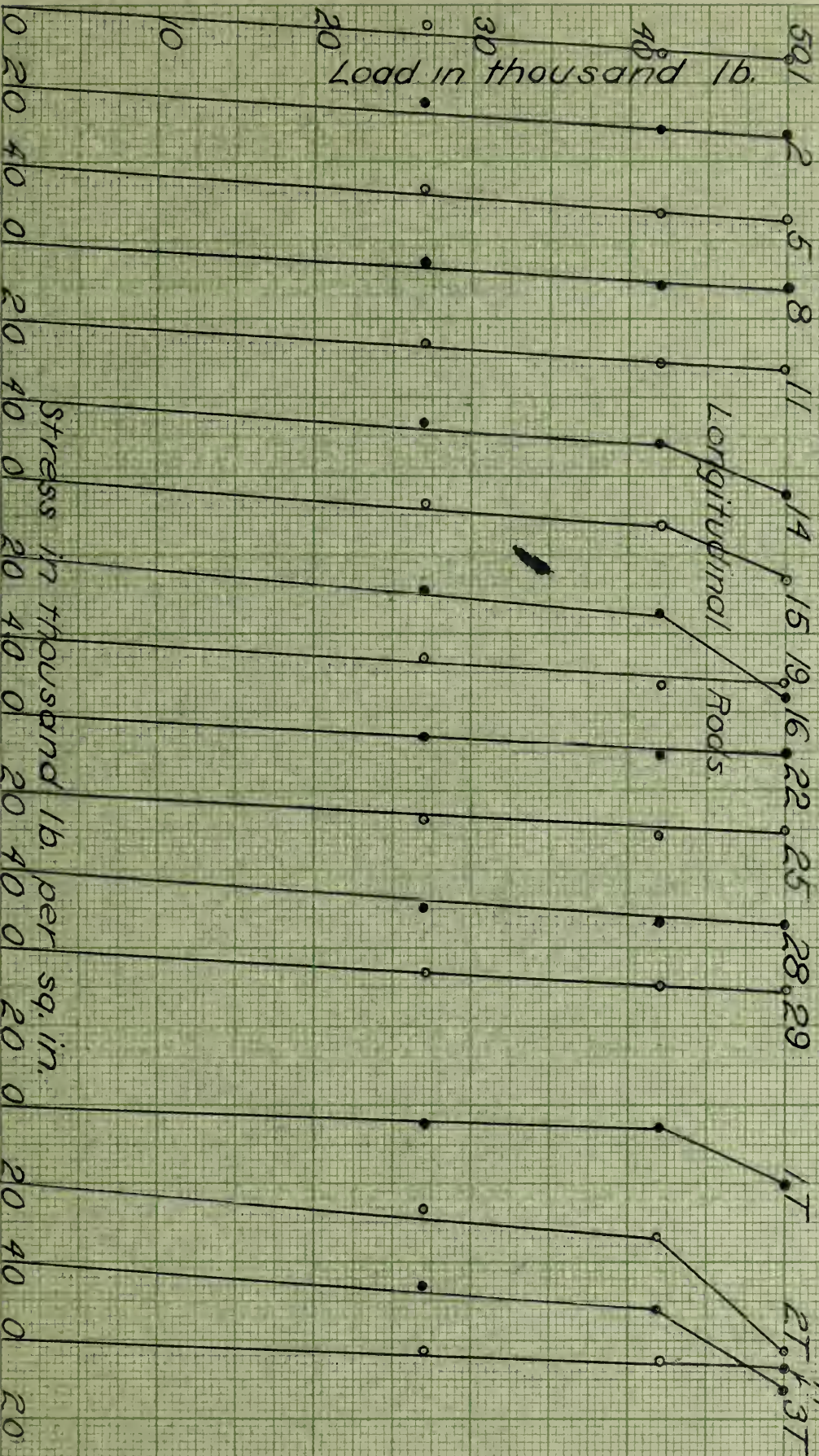
Transverse Rods

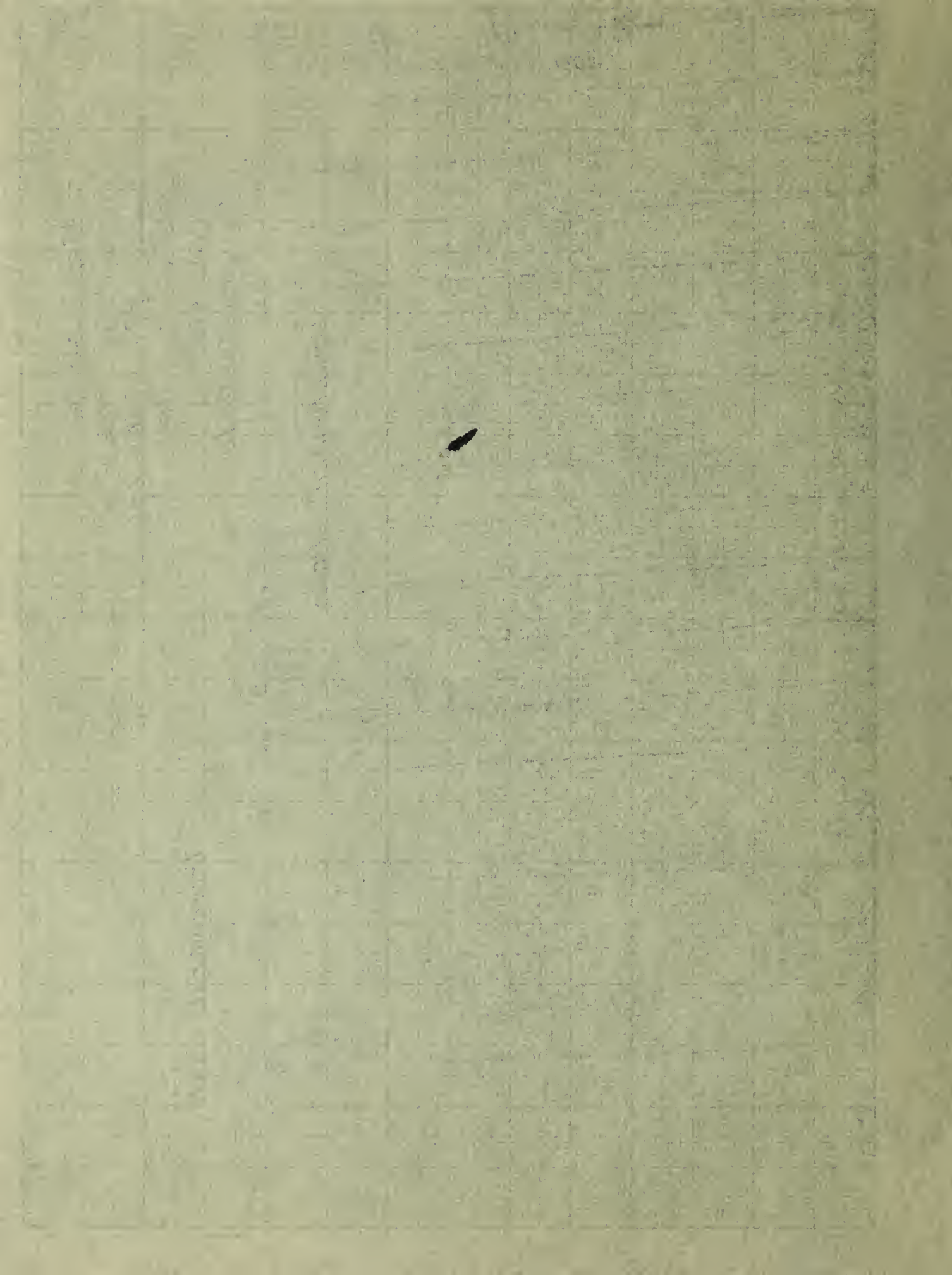
1T
2T
3T
4T

Longitudinal Rods

Load in thousand lb.

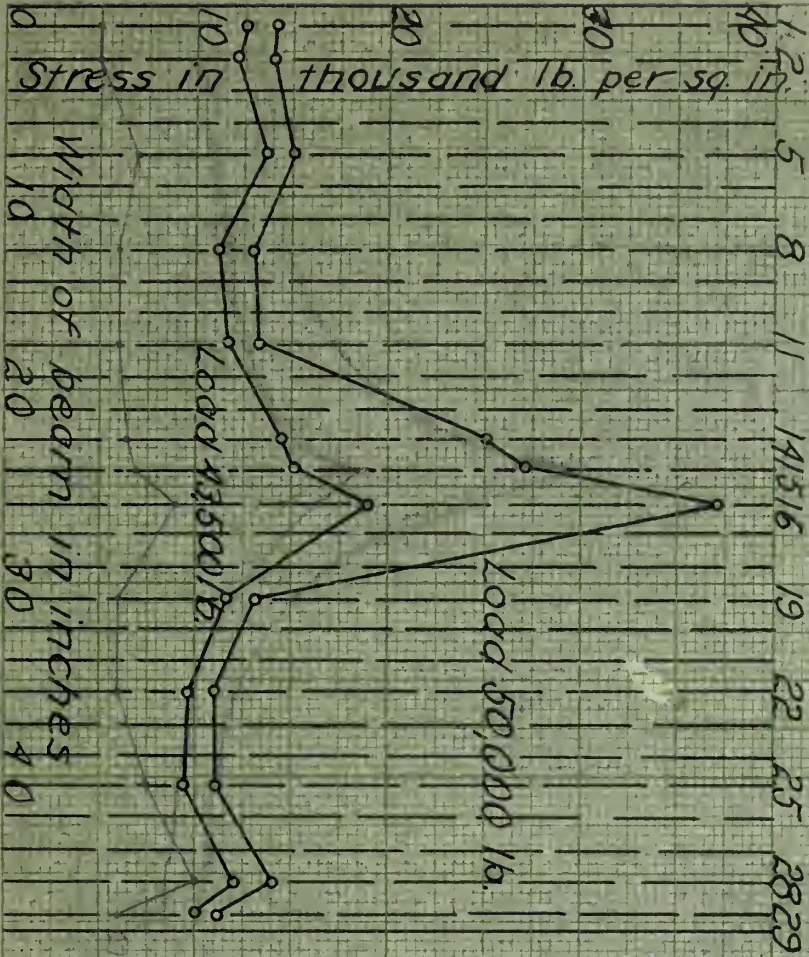
Stress in thousand lb. per sq. in.



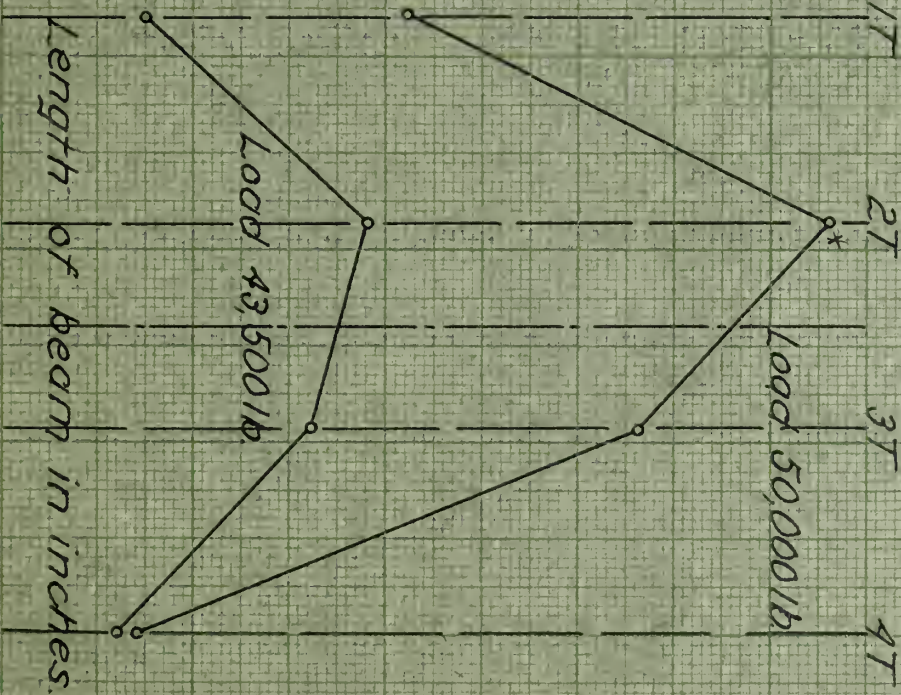


Beam No. 7541
 Rods No. Size %
 Long 29 7/16" 1.51
 Trans 4 3/8" .23
 Width 48"
 Max. Load 50,000 lb.

Longitudinal Rods



Transverse Rods



1894

1. *Chlorophyll a* is the primary photosynthetic pigment in most plants. It is a green pigment that absorbs light energy in the blue-violet and red-orange regions of the visible spectrum.

[Faint handwritten notes, mostly illegible due to fading.]

[Faint handwritten notes at the bottom of the page]

1. What is the purpose of the study?
 2. What are the research objectives?
 3. What is the research methodology?
 4. What are the results of the study?
 5. What are the conclusions of the study?
 6. What are the limitations of the study?
 7. What are the implications of the study?
 8. What are the future research directions?
 9. What are the contributions of the study?
 10. What are the key findings of the study?

[Faint handwritten notes at the bottom of the page, mostly illegible.]

[Faint handwritten notes, mostly illegible due to fading.]

1. $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$
 2. $\frac{1}{2} \times \frac{1}{4} = \frac{1}{8}$
 3. $\frac{1}{4} \times \frac{1}{4} = \frac{1}{16}$
 4. $\frac{1}{2} \times \frac{1}{8} = \frac{1}{16}$
 5. $\frac{1}{4} \times \frac{1}{8} = \frac{1}{32}$
 6. $\frac{1}{2} \times \frac{1}{16} = \frac{1}{32}$
 7. $\frac{1}{4} \times \frac{1}{16} = \frac{1}{64}$
 8. $\frac{1}{2} \times \frac{1}{32} = \frac{1}{64}$
 9. $\frac{1}{4} \times \frac{1}{32} = \frac{1}{128}$
 10. $\frac{1}{2} \times \frac{1}{64} = \frac{1}{128}$
 11. $\frac{1}{4} \times \frac{1}{128} = \frac{1}{256}$
 12. $\frac{1}{2} \times \frac{1}{256} = \frac{1}{256}$
 13. $\frac{1}{4} \times \frac{1}{256} = \frac{1}{512}$
 14. $\frac{1}{2} \times \frac{1}{512} = \frac{1}{512}$
 15. $\frac{1}{4} \times \frac{1}{512} = \frac{1}{1024}$
 16. $\frac{1}{2} \times \frac{1}{1024} = \frac{1}{1024}$
 17. $\frac{1}{4} \times \frac{1}{1024} = \frac{1}{2048}$
 18. $\frac{1}{2} \times \frac{1}{2048} = \frac{1}{2048}$
 19. $\frac{1}{4} \times \frac{1}{2048} = \frac{1}{4096}$
 20. $\frac{1}{2} \times \frac{1}{4096} = \frac{1}{4096}$
 21. $\frac{1}{4} \times \frac{1}{4096} = \frac{1}{8192}$
 22. $\frac{1}{2} \times \frac{1}{8192} = \frac{1}{8192}$
 23. $\frac{1}{4} \times \frac{1}{8192} = \frac{1}{16384}$
 24. $\frac{1}{2} \times \frac{1}{16384} = \frac{1}{16384}$
 25. $\frac{1}{4} \times \frac{1}{16384} = \frac{1}{32768}$
 26. $\frac{1}{2} \times \frac{1}{32768} = \frac{1}{32768}$
 27. $\frac{1}{4} \times \frac{1}{32768} = \frac{1}{65536}$
 28. $\frac{1}{2} \times \frac{1}{65536} = \frac{1}{65536}$
 29. $\frac{1}{4} \times \frac{1}{65536} = \frac{1}{131072}$
 30. $\frac{1}{2} \times \frac{1}{131072} = \frac{1}{131072}$
 31. $\frac{1}{4} \times \frac{1}{131072} = \frac{1}{262144}$
 32. $\frac{1}{2} \times \frac{1}{262144} = \frac{1}{262144}$
 33. $\frac{1}{4} \times \frac{1}{262144} = \frac{1}{524288}$
 34. $\frac{1}{2} \times \frac{1}{524288} = \frac{1}{524288}$
 35. $\frac{1}{4} \times \frac{1}{524288} = \frac{1}{1048576}$
 36. $\frac{1}{2} \times \frac{1}{1048576} = \frac{1}{1048576}$
 37. $\frac{1}{4} \times \frac{1}{1048576} = \frac{1}{2097152}$
 38. $\frac{1}{2} \times \frac{1}{2097152} = \frac{1}{2097152}$
 39. $\frac{1}{4} \times \frac{1}{2097152} = \frac{1}{4194304}$
 40. $\frac{1}{2} \times \frac{1}{4194304} = \frac{1}{4194304}$
 41. $\frac{1}{4} \times \frac{1}{4194304} = \frac{1}{8388608}$
 42. $\frac{1}{2} \times \frac{1}{8388608} = \frac{1}{8388608}$
 43. $\frac{1}{4} \times \frac{1}{8388608} = \frac{1}{16777216}$
 44. $\frac{1}{2} \times \frac{1}{16777216} = \frac{1}{16777216}$
 45. $\frac{1}{4} \times \frac{1}{16777216} = \frac{1}{33554432}$
 46. $\frac{1}{2} \times \frac{1}{33554432} = \frac{1}{33554432}$
 47. $\frac{1}{4} \times \frac{1}{33554432} = \frac{1}{67108864}$
 48. $\frac{1}{2} \times \frac{1}{67108864} = \frac{1}{67108864}$
 49. $\frac{1}{4} \times \frac{1}{67108864} = \frac{1}{134217728}$
 50. $\frac{1}{2} \times \frac{1}{134217728} = \frac{1}{134217728}$
 51. $\frac{1}{4} \times \frac{1}{134217728} = \frac{1}{268435456}$
 52. $\frac{1}{2} \times \frac{1}{268435456} = \frac{1}{268435456}$
 53. $\frac{1}{4} \times \frac{1}{268435456} = \frac{1}{536870912}$
 54. $\frac{1}{2} \times \frac{1}{536870912} = \frac{1}{536870912}$
 55. $\frac{1}{4} \times \frac{1}{536870912} = \frac{1}{1073741824}$
 56. $\frac{1}{2} \times \frac{1}{1073741824} = \frac{1}{1073741824}$
 57. $\frac{1}{4} \times \frac{1}{1073741824} = \frac{1}{2147483648}$
 58. $\frac{1}{2} \times \frac{1}{2147483648} = \frac{1}{2147483648}$
 59. $\frac{1}{4} \times \frac{1}{2147483648} = \frac{1}{4294967296}$
 60. $\frac{1}{2} \times \frac{1}{4294967296} = \frac{1}{4294967296}$
 61. $\frac{1}{4} \times \frac{1}{4294967296} = \frac{1}{8589934592}$
 62. $\frac{1}{2} \times \frac{1}{8589934592} = \frac{1}{8589934592}$
 63. $\frac{1}{4} \times \frac{1}{8589934592} = \frac{1}{17179869184}$
 64. $\frac{1}{2} \times \frac{1}{17179869184} = \frac{1}{17179869184}$
 65. $\frac{1}{4} \times \frac{1}{17179869184} = \frac{1}{34359738368}$
 66. $\frac{1}{2} \times \frac{1}{34359738368} = \frac{1}{34359738368}$
 67. $\frac{1}{4} \times \frac{1}{34359738368} = \frac{1}{68719476736}$
 68. $\frac{1}{2} \times \frac{1}{68719476736} = \frac{1}{68719476736}$
 69. $\frac{1}{4} \times \frac{1}{68719476736} = \frac{1}{137438953472}$
 70. $\frac{1}{2} \times \frac{1}{137438953472} = \frac{1}{137438953472}$
 71. $\frac{1}{4} \times \frac{1}{137438953472} = \frac{1}{274877906944}$
 72. $\frac{1}{2} \times \frac{1}{274877906944} = \frac{1}{274877906944}$
 73. $\frac{1}{4} \times \frac{1}{274877906944} = \frac{1}{549755813888}$
 74. $\frac{1}{2} \times \frac{1}{549755813888} = \frac{1}{549755813888}$
 75. $\frac{1}{4} \times \frac{1}{549755813888} = \frac{1}{1099511627776}$
 76. $\frac{1}{2} \times \frac{1}{1099511627776} = \frac{1}{1099511627776}$
 77. $\frac{1}{4} \times \frac{1}{1099511627776} = \frac{1}{2199023255552}$
 78. $\frac{1}{2} \times \frac{1}{2199023255552} = \frac{1}{2199023255552}$
 79. $\frac{1}{4} \times \frac{1}{2199023255552} = \frac{1}{4398046511104}$
 80. $\frac{1}{2} \times \frac{1}{4398046511104} = \frac{1}{4398046511104}$
 81. $\frac{1}{4} \times \frac{1}{4398046511104} = \frac{1}{8796093022208}$
 82. $\frac{1}{2} \times \frac{1}{8796093022208} = \frac{1}{8796093022208}$
 83. $\frac{1}{4} \times \frac{1}{8796093022208} = \frac{1}{17592186044416}$
 84. $\frac{1}{2} \times \frac{1}{17592186044416} = \frac{1}{175921$

[Faint, illegible handwritten notes]

The image shows a single page of a handwritten manuscript. The text is written in a cursive script, likely from the 17th or 18th century. The paper is aged, with visible creases, stains, and some discoloration. The handwriting is dense and fills most of the page, with some lines starting with capital letters. The overall appearance is that of a historical document.

Handwritten notes on lined paper, including the word "Handwritten" and various scribbles and markings.

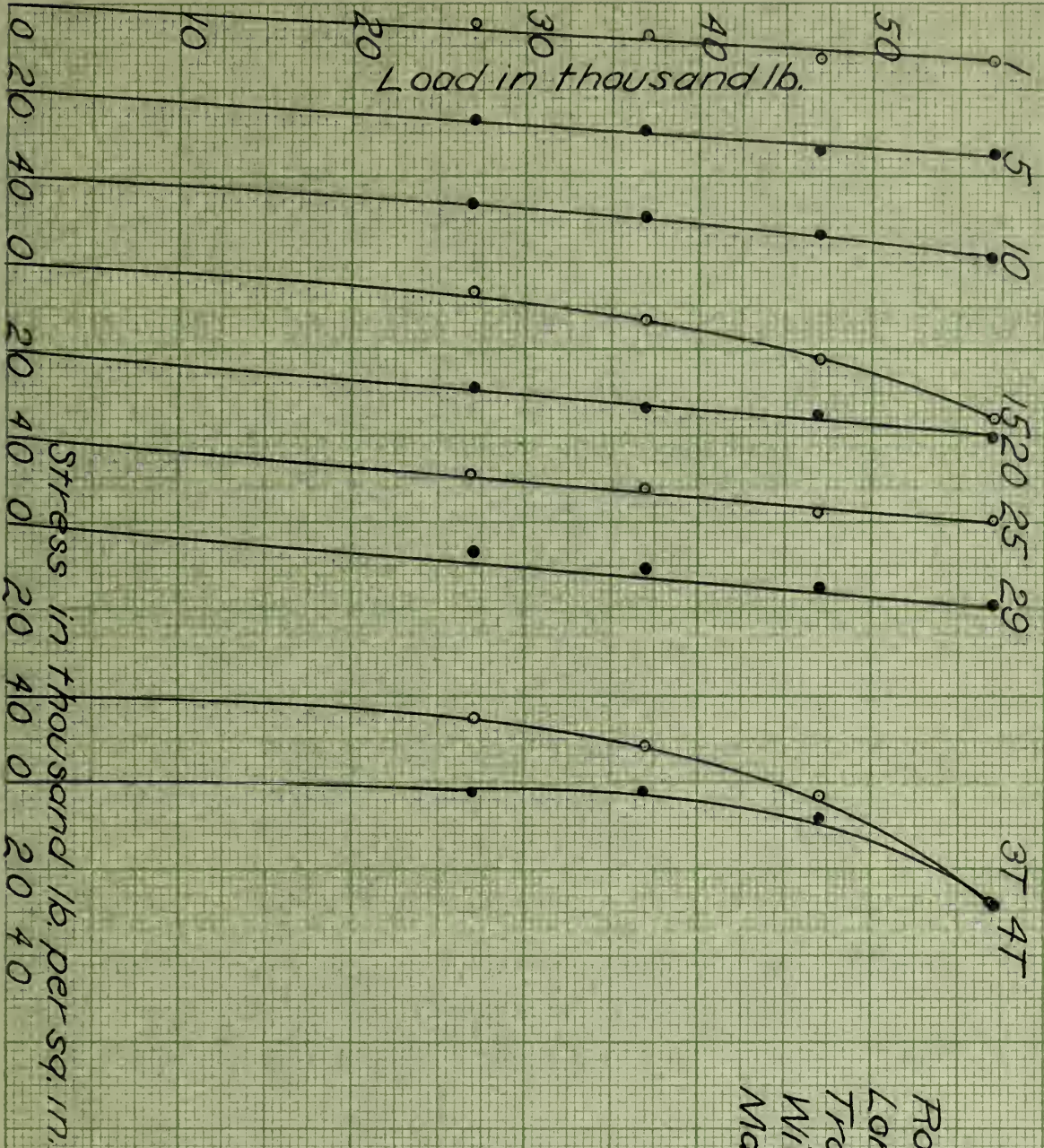
1. Die erste Gruppe ist die Gruppe der „Kleinrentner“. Diese Gruppe ist die größte Gruppe und besteht aus denjenigen, die eine kleine Rente erhalten. Sie sind in der Regel älter und haben eine geringere Lebenserwartung.

[Faint handwritten notes at the bottom of the page]

1890

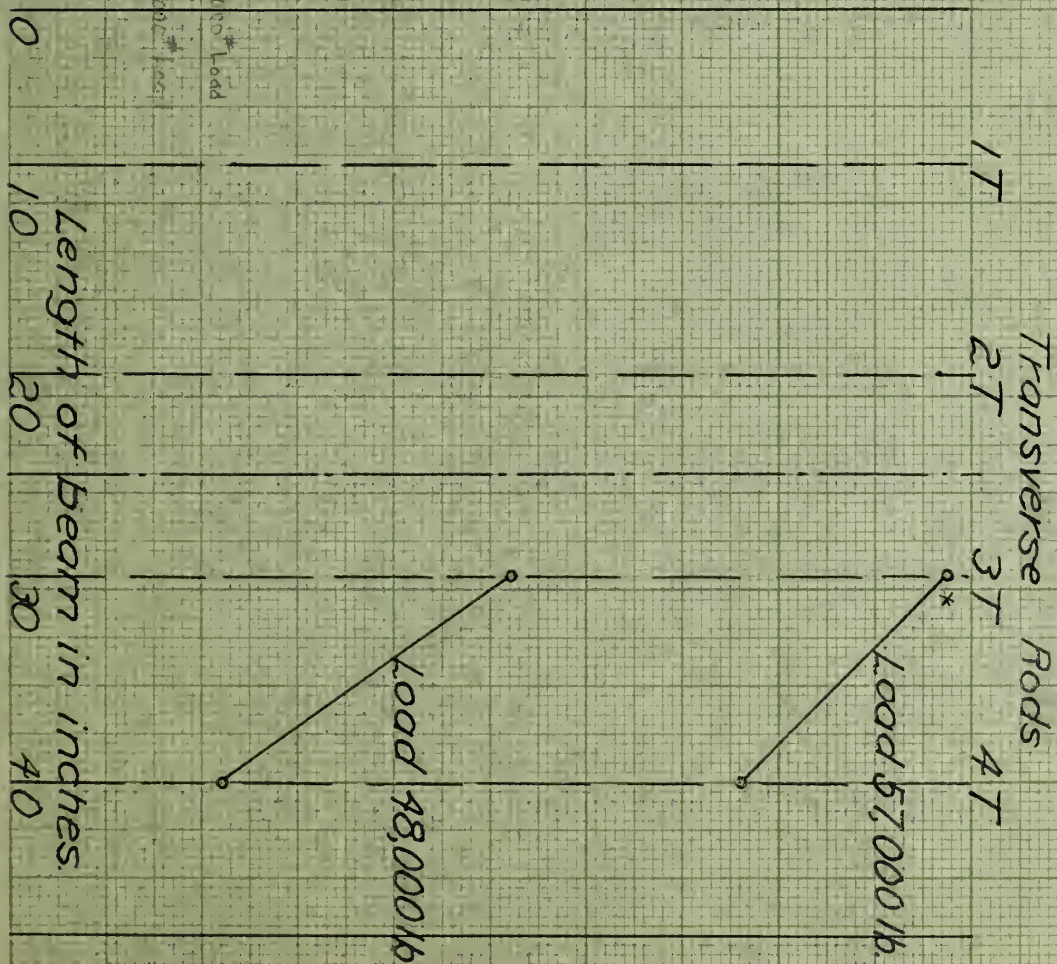
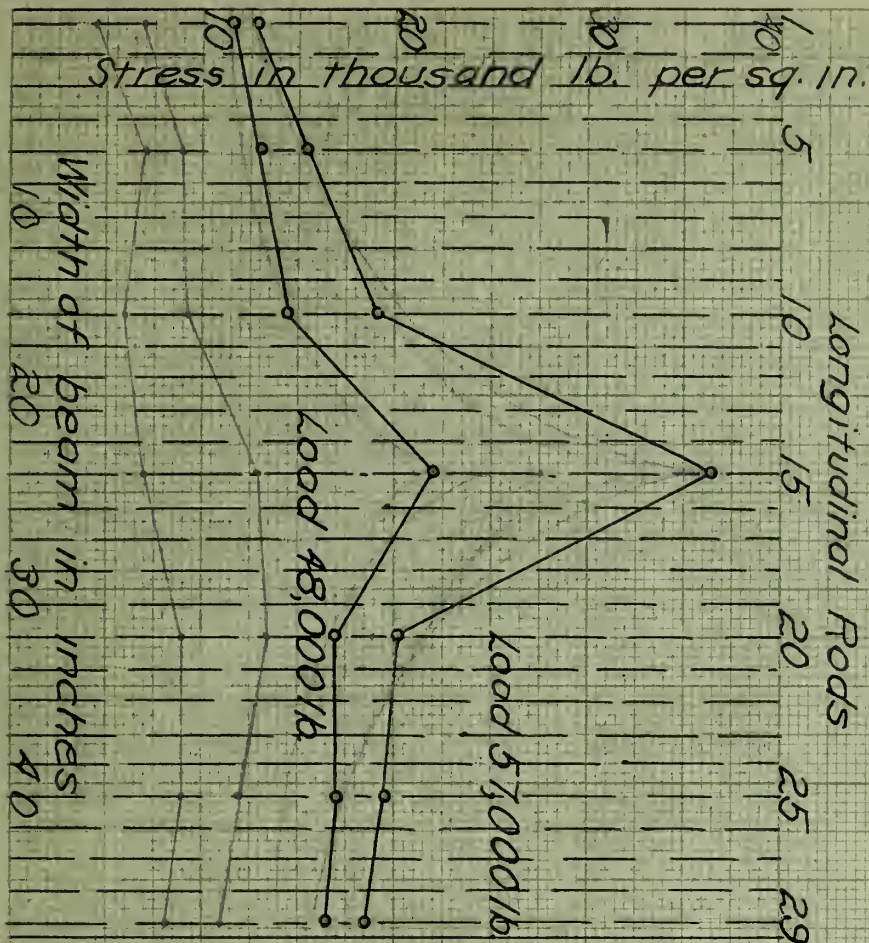
Longitudinal Rods.

Transverse Rods.



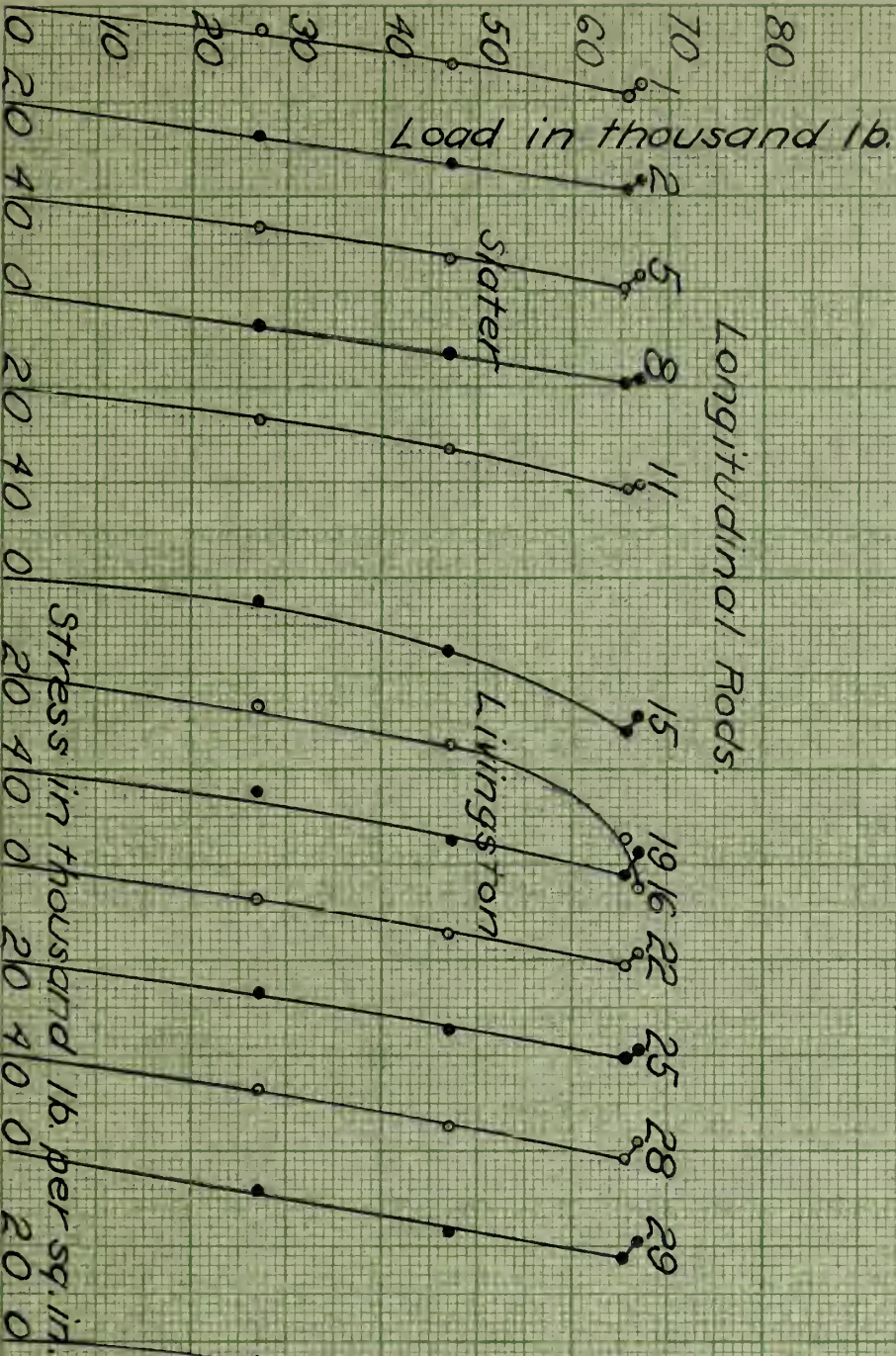
Beam No. 754.2
 Rods No. Size %
 Long. 29 7/16" 1.51
 Trans 4 3/8" .22
 Width 48"
 Max. Load 57,000 lb.

Beam No 7542
 Rods No Size %
 Long 29 7/16" 1.51
 Trans. 4 3/8" .23
 Width 48"
 Max. Load 57,000 lb.

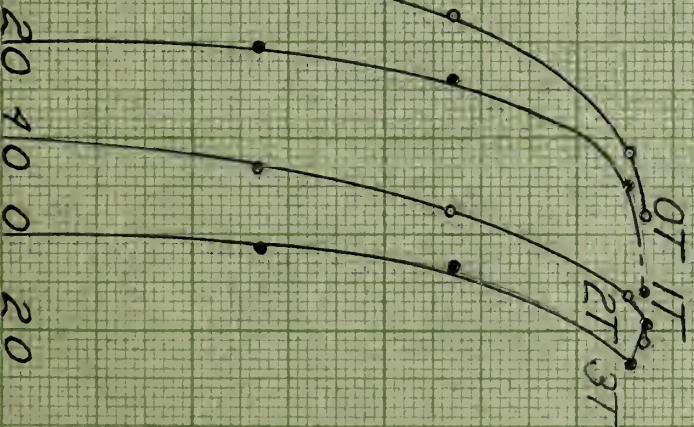


Beam No. 755.1
 Rods No. Size %
 Long. 29 7/16" 1.51
 Trans. 8 3/8" .46
 Width 48"
 Max. Load 67,000 lb

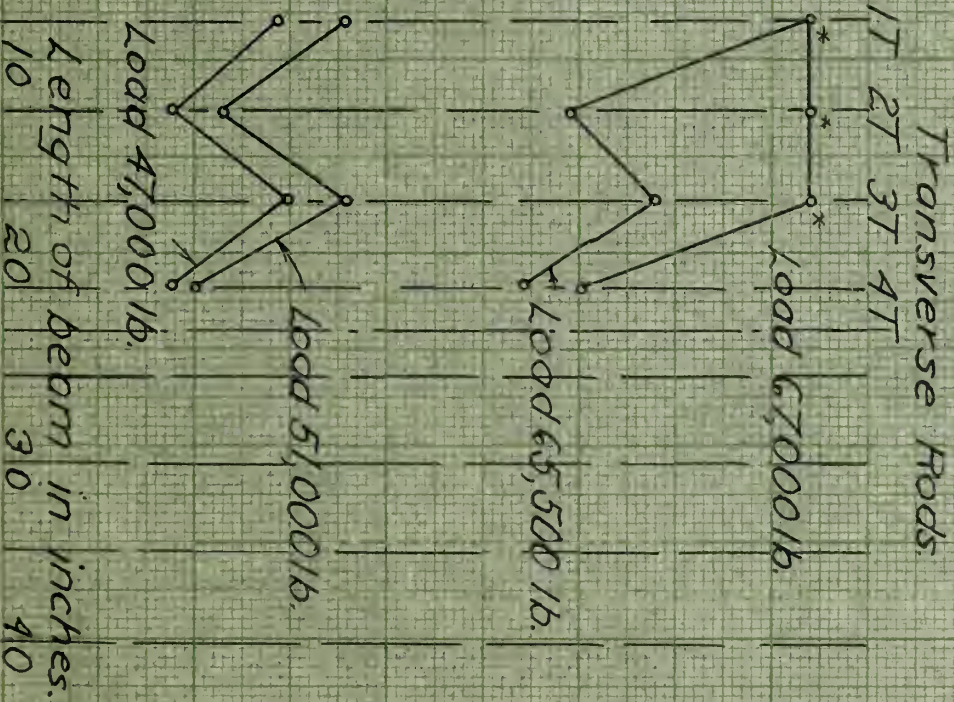
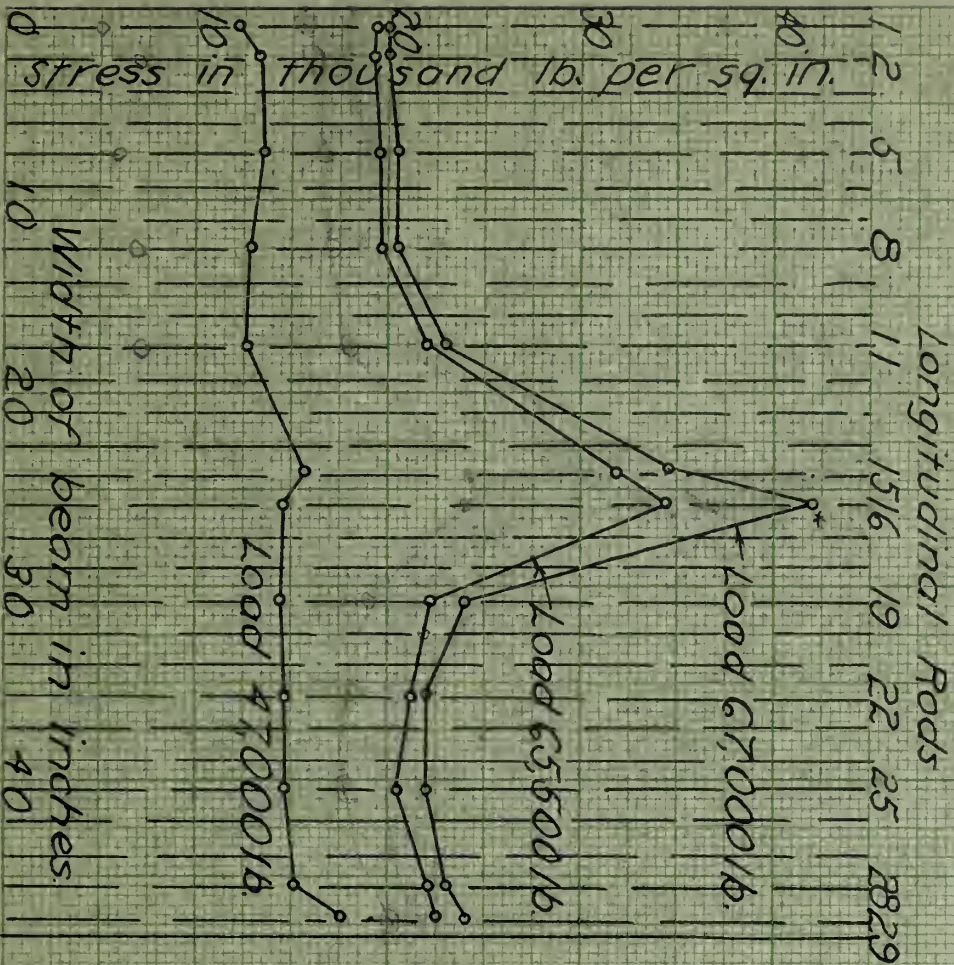
Longitudinal Rods.



Transverse Rods.

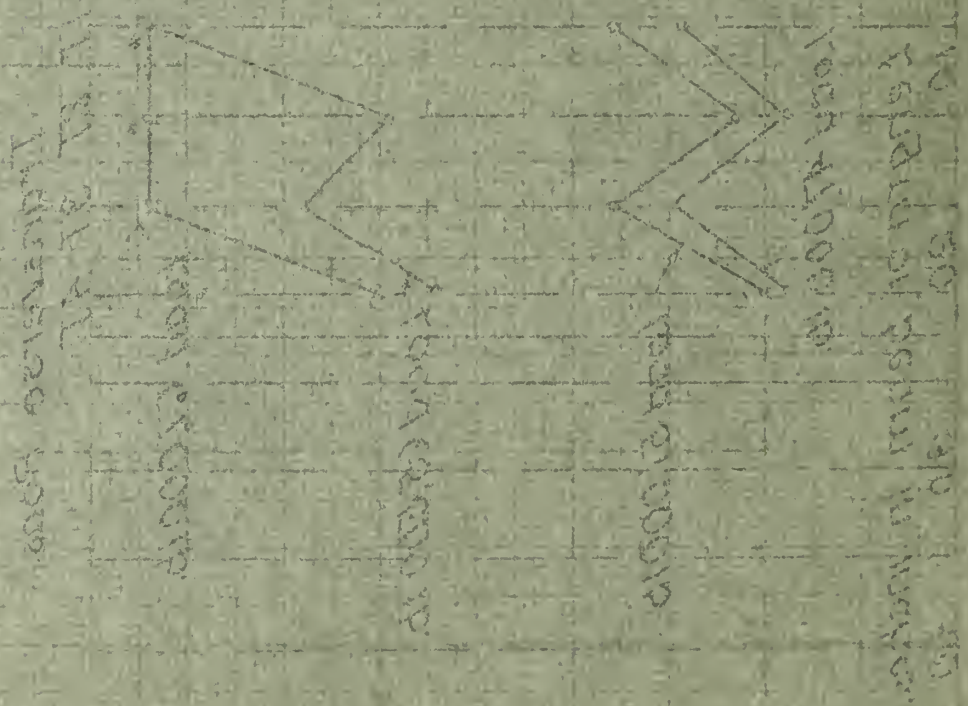
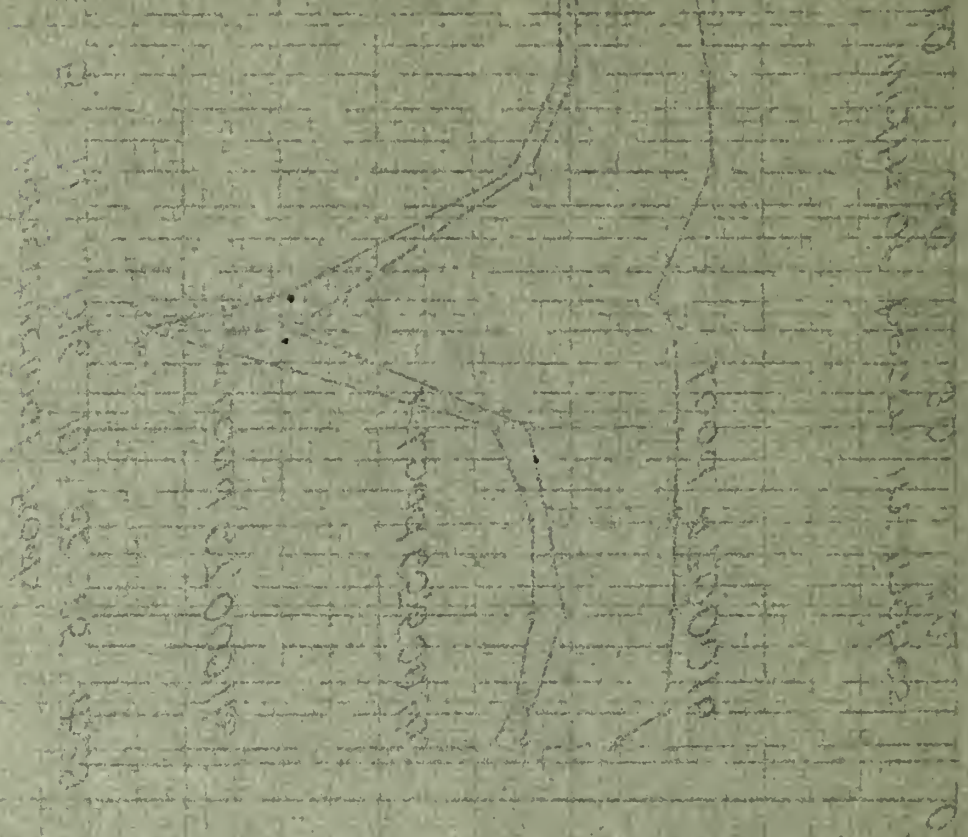


Beam No. 7551
 Rods No. Size ϕ
 Long. 29 $7/16"$ 151
 Trans. 8 $3/8"$ 96
 Width 48"
 Max. Load 67,000 lb.

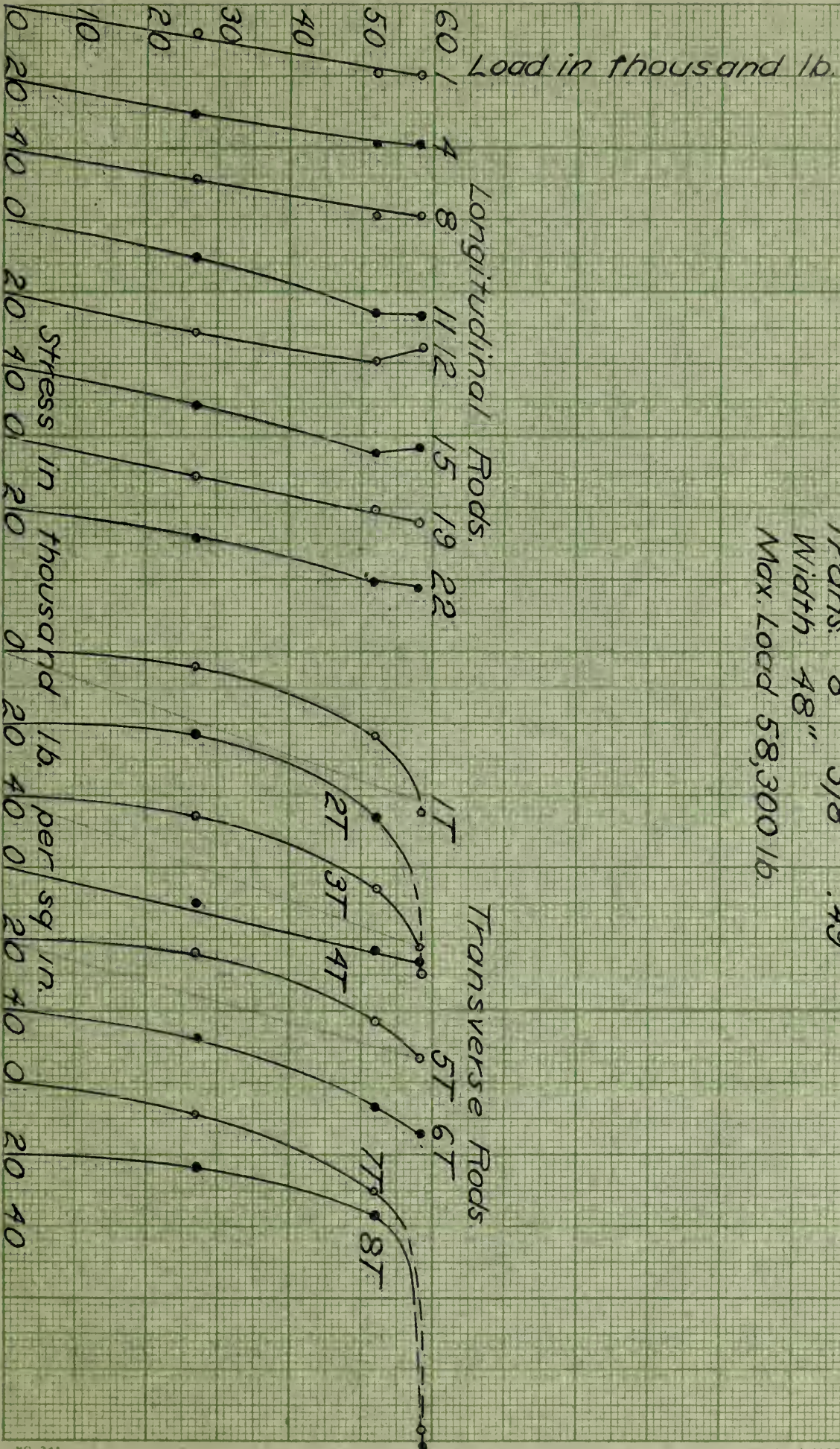


Handwritten header text at the top of the page, possibly a title or date.

Vertical handwritten text on the left side of the page, likely a list or index.

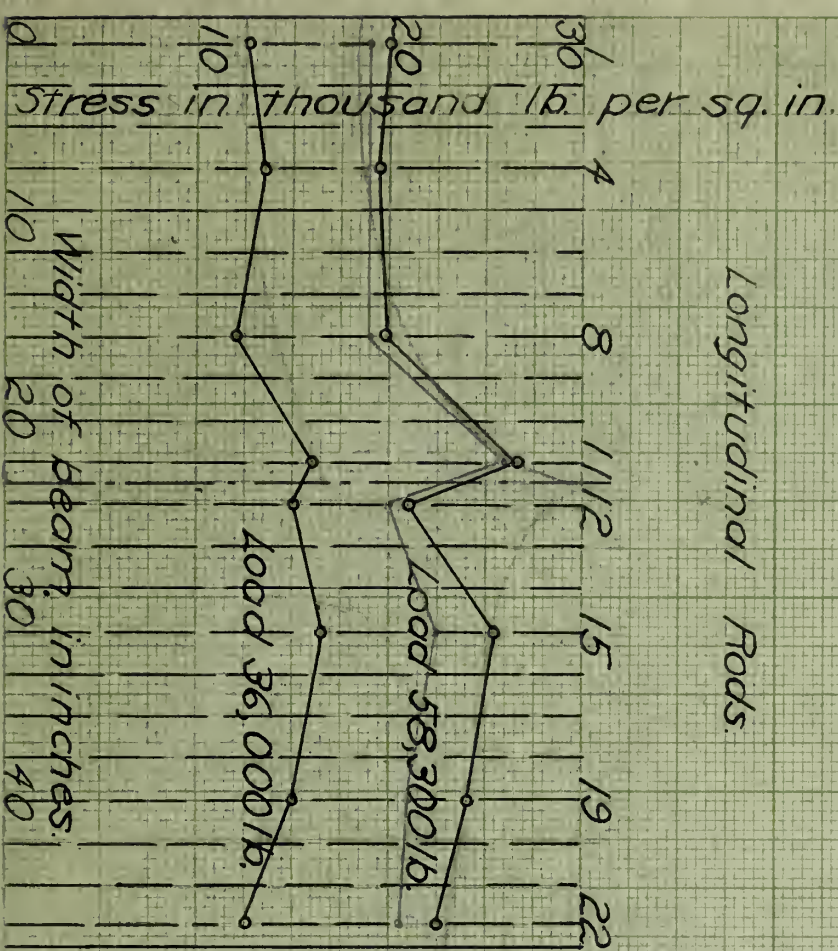


Beam No 755.2
 Rods No. Size %
 Long. 22 1/2" 1.51
 Trans. 8 3/8" .49
 Width 48"
 Max. Load 58,300 lb.

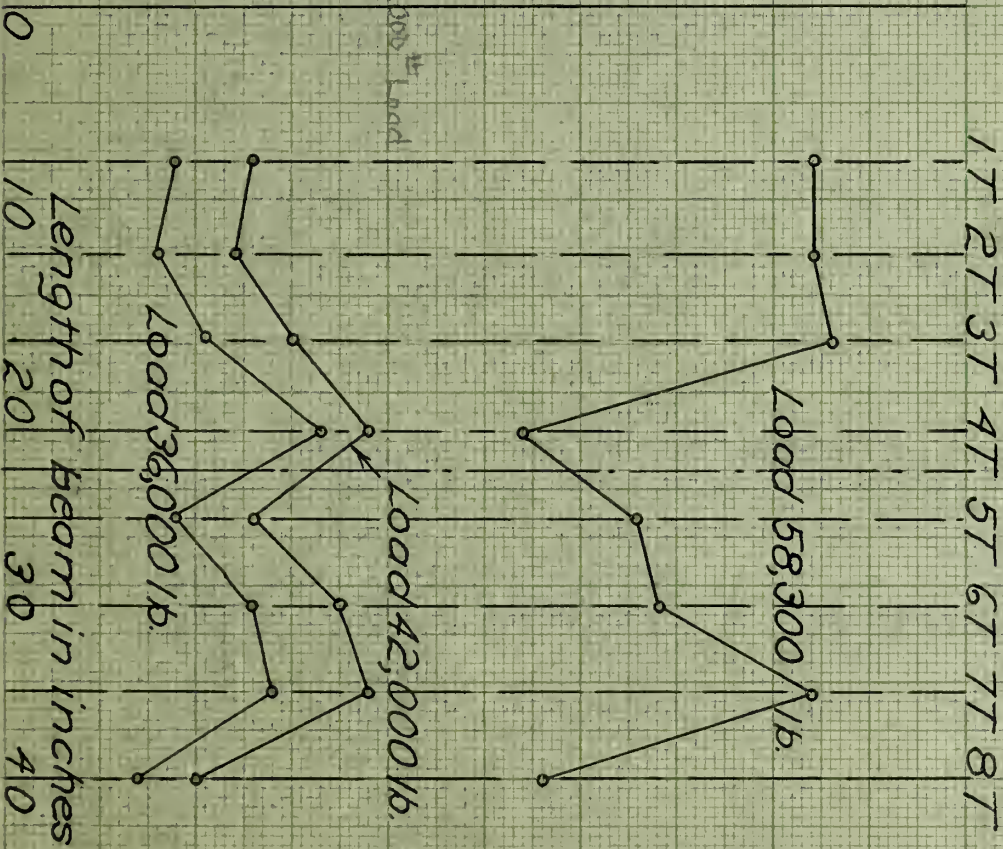


Beam No. 755.2
 Rods No. Size %
 Long. 22 1/2" 1.51
 Trans. 8 3/8" .46
 Width 48"
 Max. Load 58,300 lb.

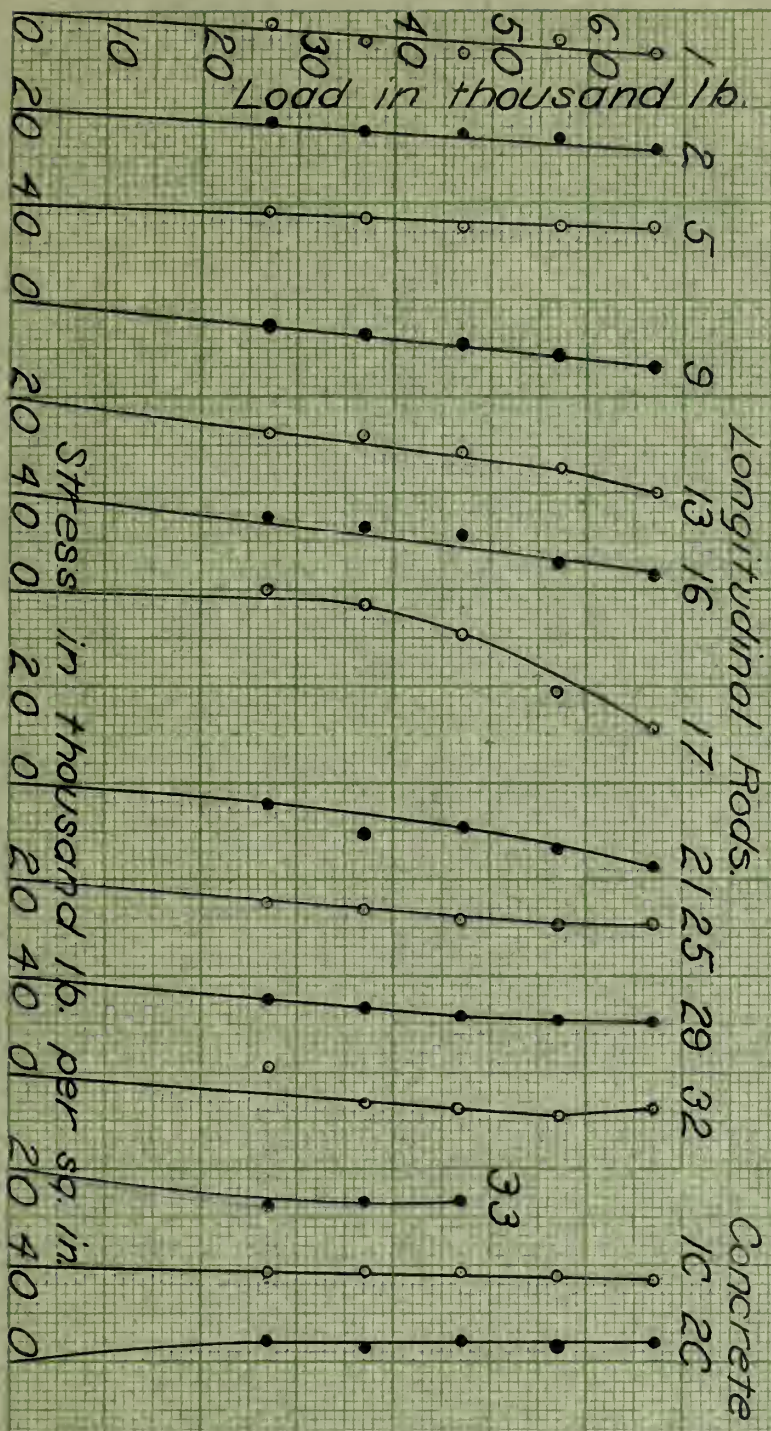
Longitudinal Rods



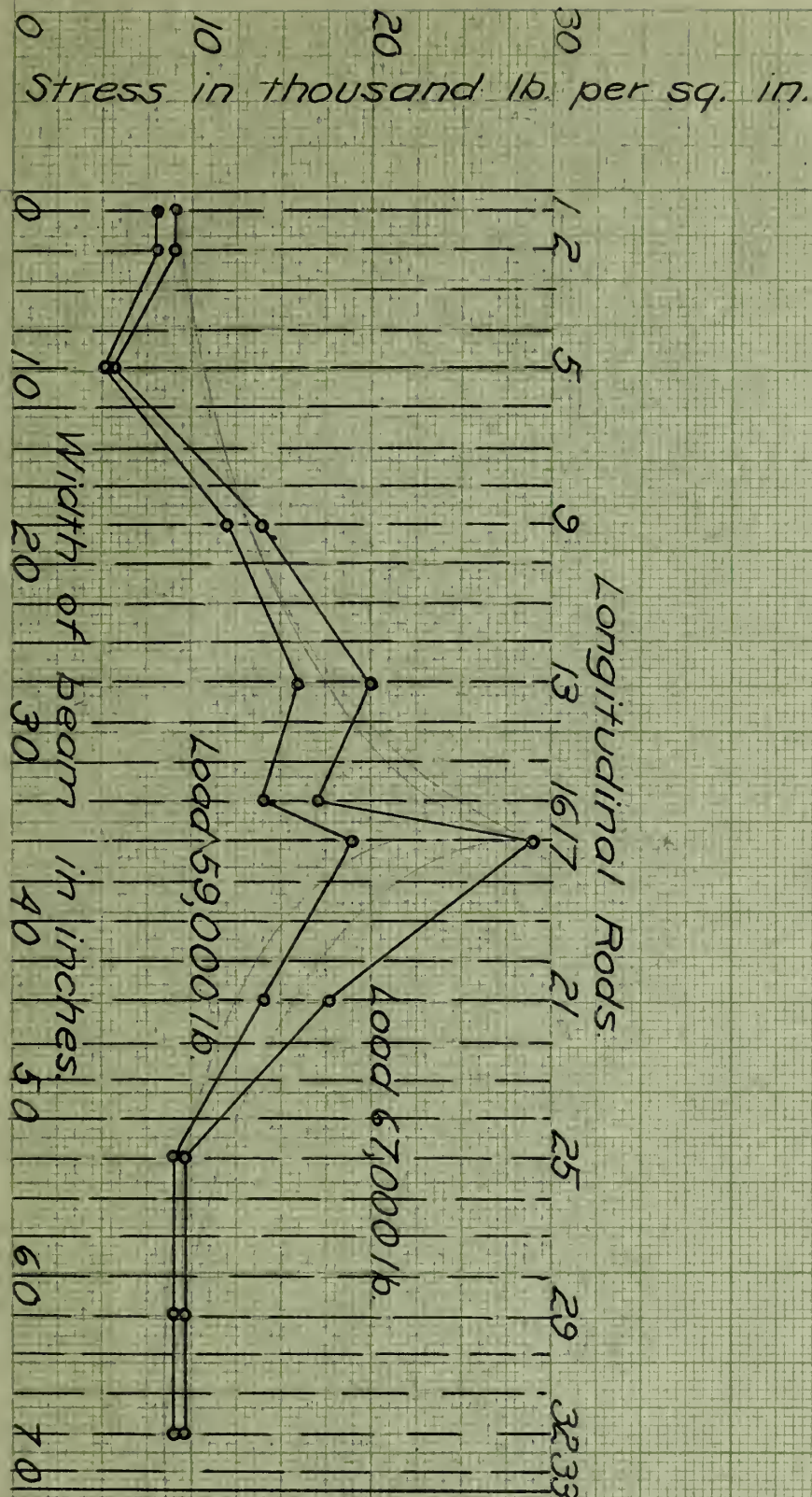
Transverse Rods



Beam No 756.1
 Rods No. Size %
 Long. 33 1/2" 1.5
 Trans. 4 3/8" .23
 Width 72"
 Max Load 68,000 lb.

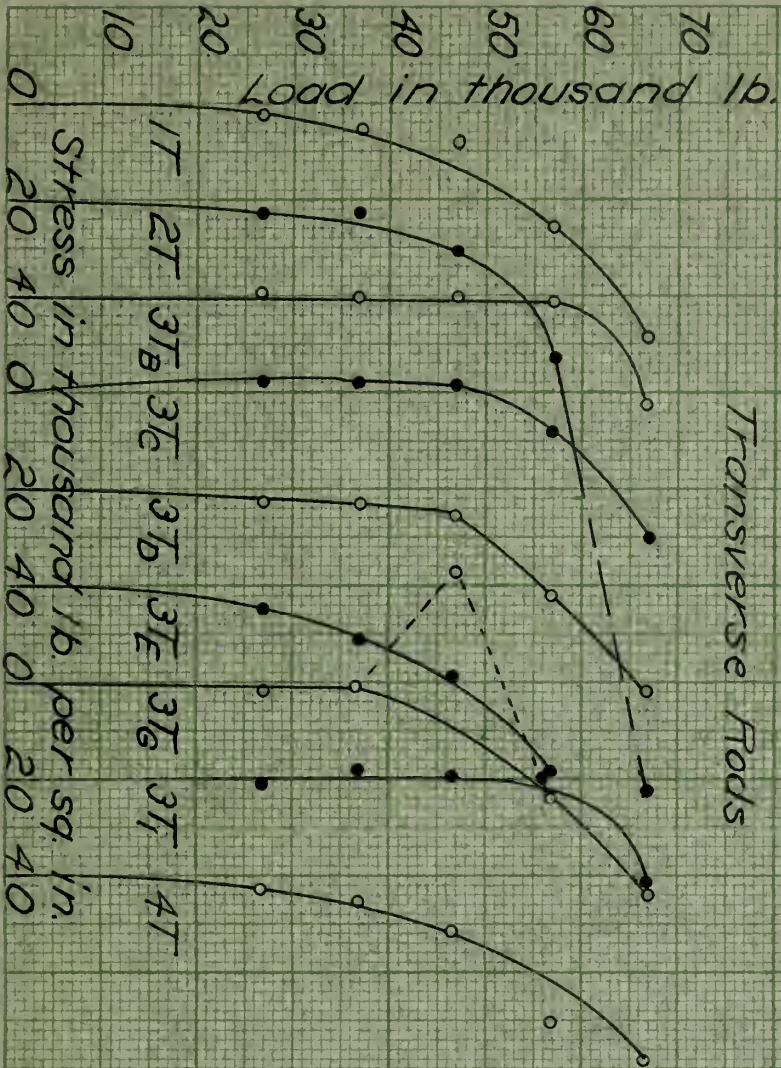


Beam No. 756.1
 Rods No. Size %
 Long. 33 1 1/2" 1.50
 Trans. 4 3/8" .23
 Width 72"
 Max. Load 68,000 lb.



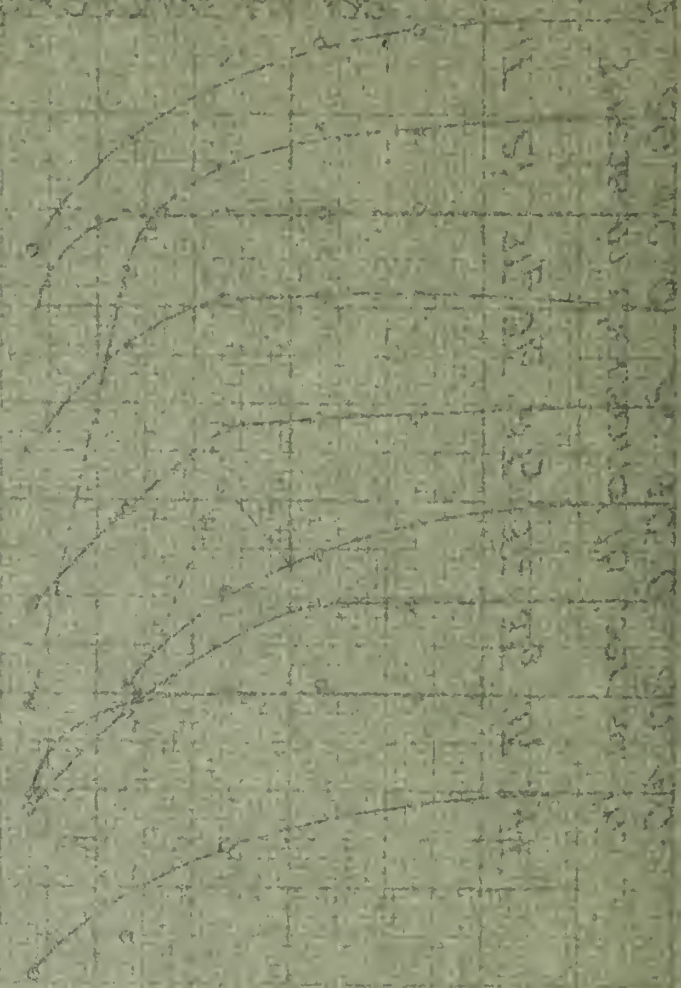
Beam No. 756.1
 Rods No. 33
 Long 1 1/2"
 Trans. 4
 Width 72"
 Max. Load 68,000 lb.
 .23

Transverse Rods



0 2 5 8 9 5 0

10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100



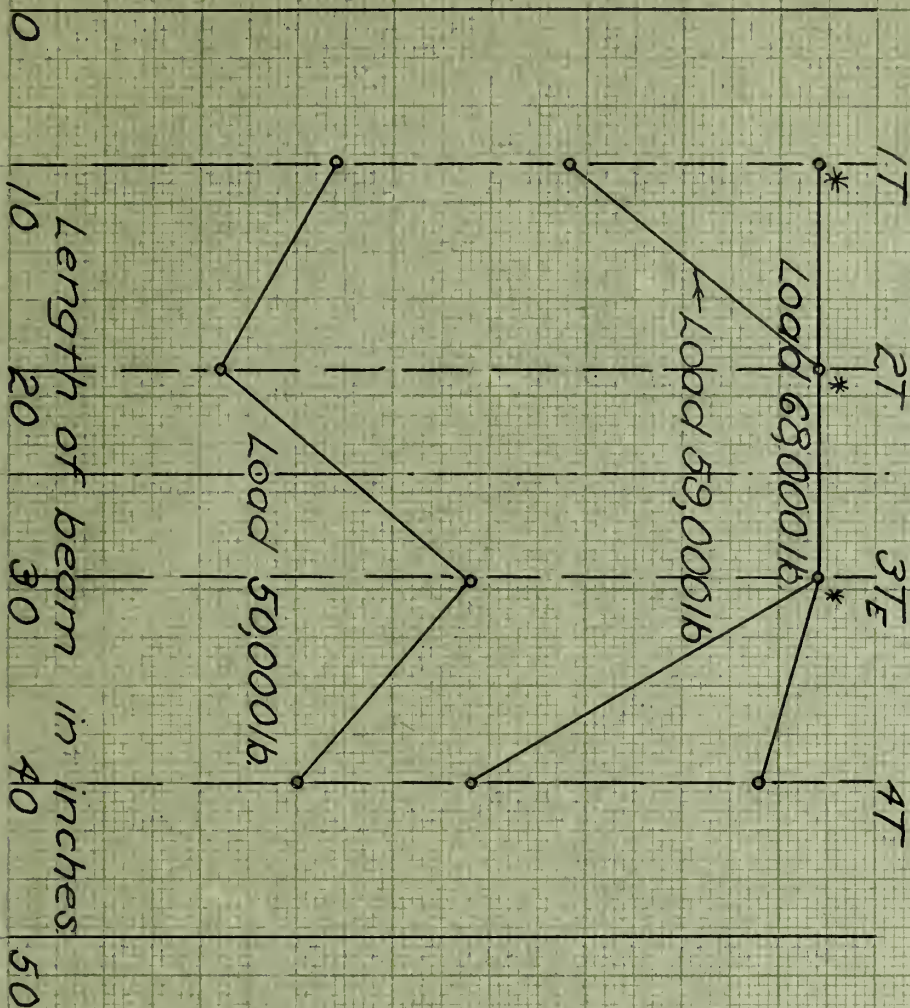
100
90
80
70
60
50
40
30
20
10
0

100
90
80
70
60
50
40
30
20
10
0

100
90
80
70
60
50
40
30
20
10
0

Beam No. 756.1
 Rods No. Size %
 Long. 33 1/2" 1.50
 Trans 4 3/8" .23
 Width 72"
 Max. Load 68,000 lb.

Transverse Rods



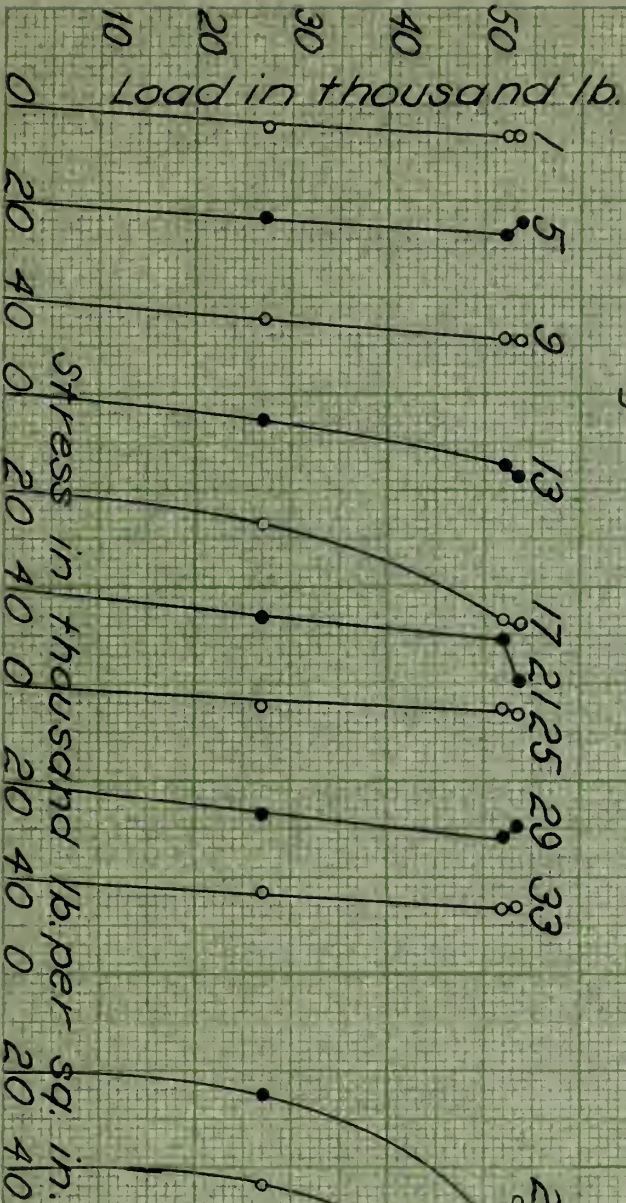
Stress in thousand lb. per sq. in.

Length of beam in inches

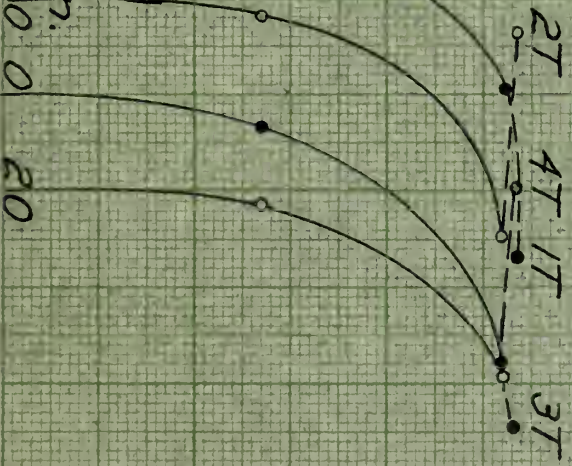
50

Beam No. 756.2
 Rods No. Size %
 Long. 33 1/2" 1.5
 Trans 4 3/8" .23
 Width 72"
 Max Load 53,500 lb.

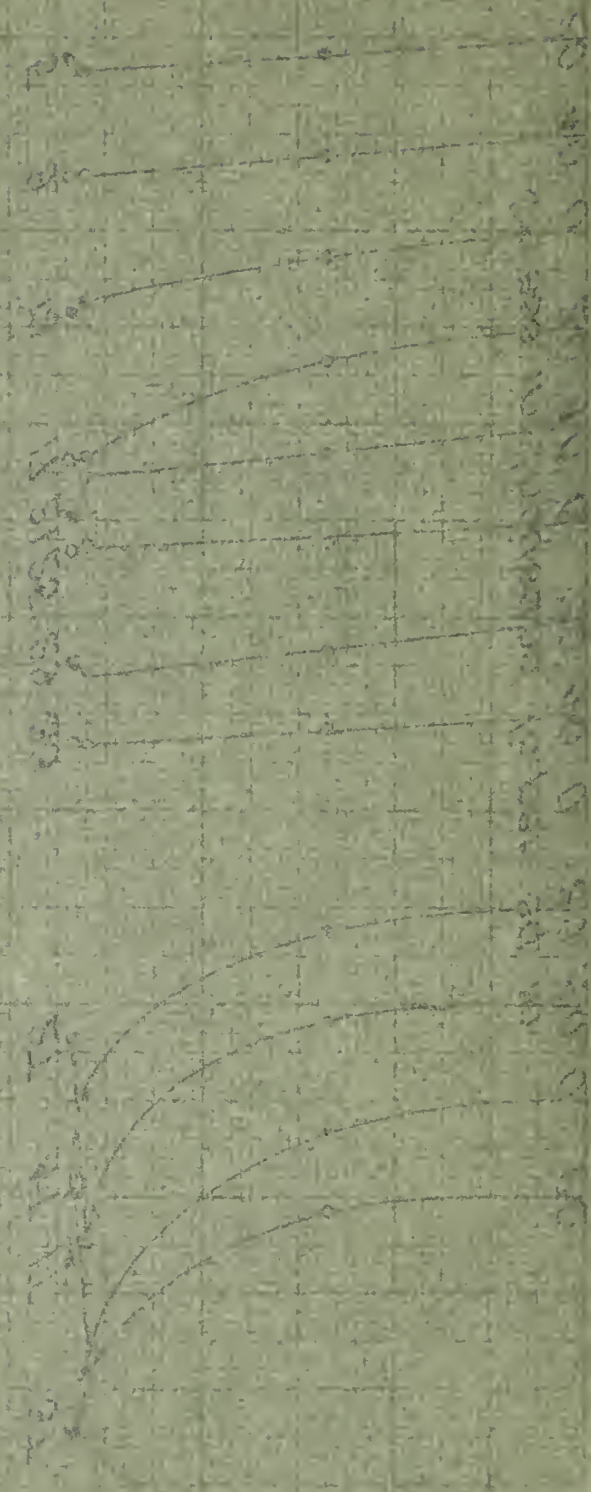
Longitudinal Rods



Transverse Rods



5 5 5 5 5
 2 2 2 2 2



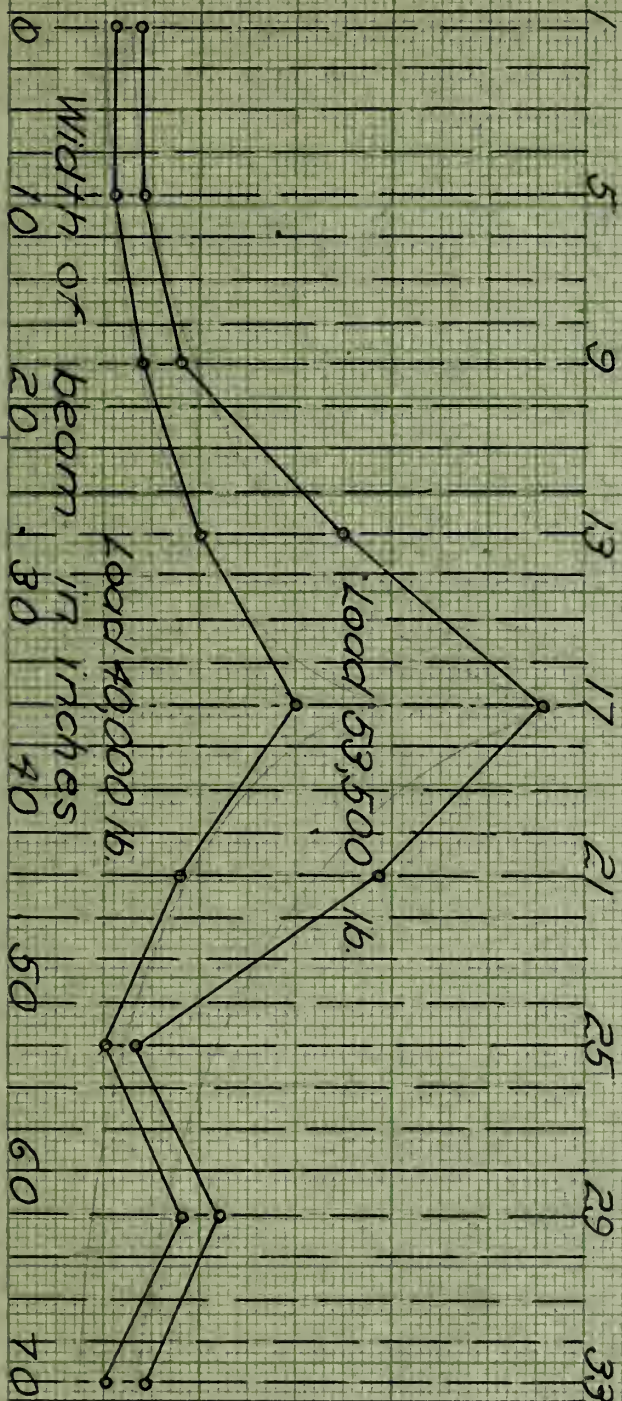
10
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 100

Beam No. 75612
 Rods No. Size %
 Long. 33 1/2" 1.50
 Trans. 4 3/8" .23
 Width 72"
 Max Load 53,500 lb.

Longitudinal Rods



Beam No. 756.2

Rods No. Size %

Long. 33 1/2" 1.50

Trans. 4 3/8" .23

Width 12"

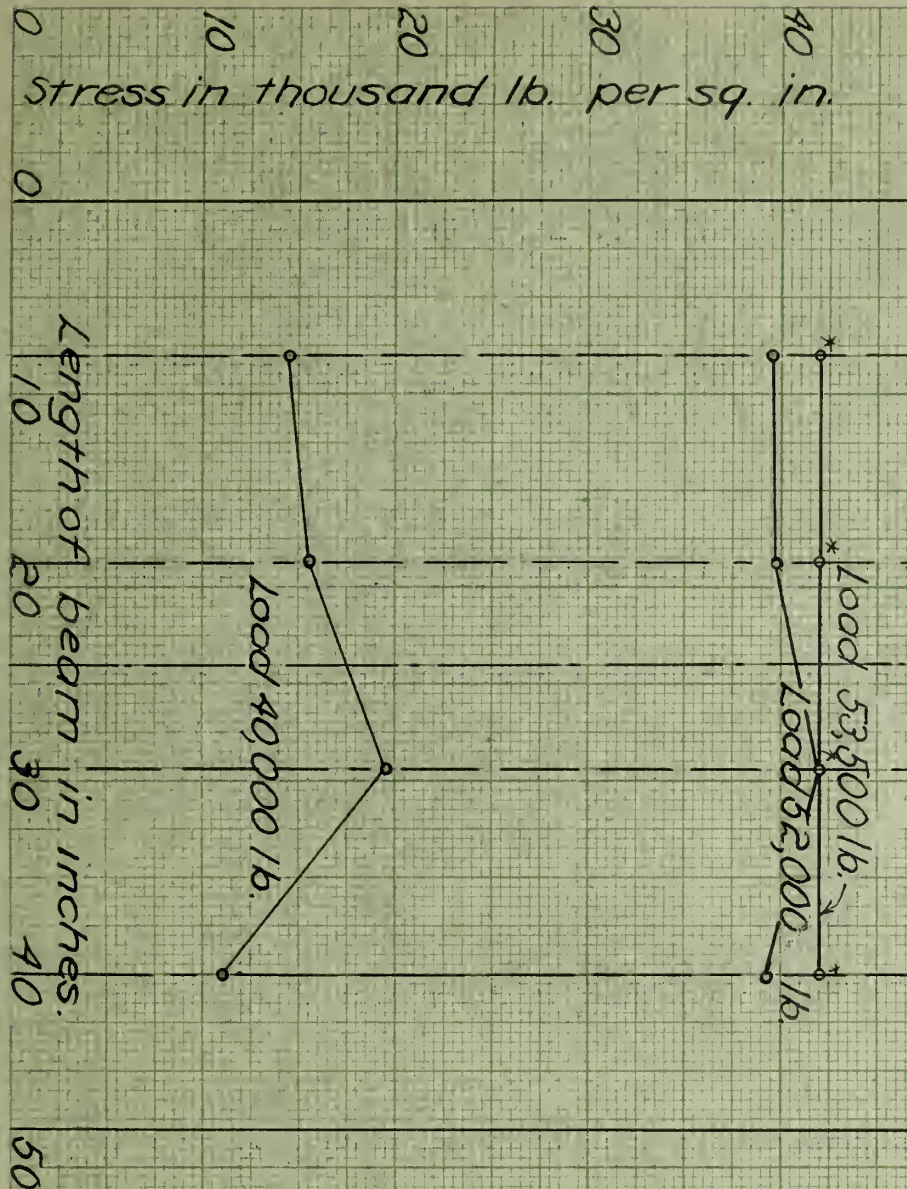
Max. Load 53,500 lb.

12

6

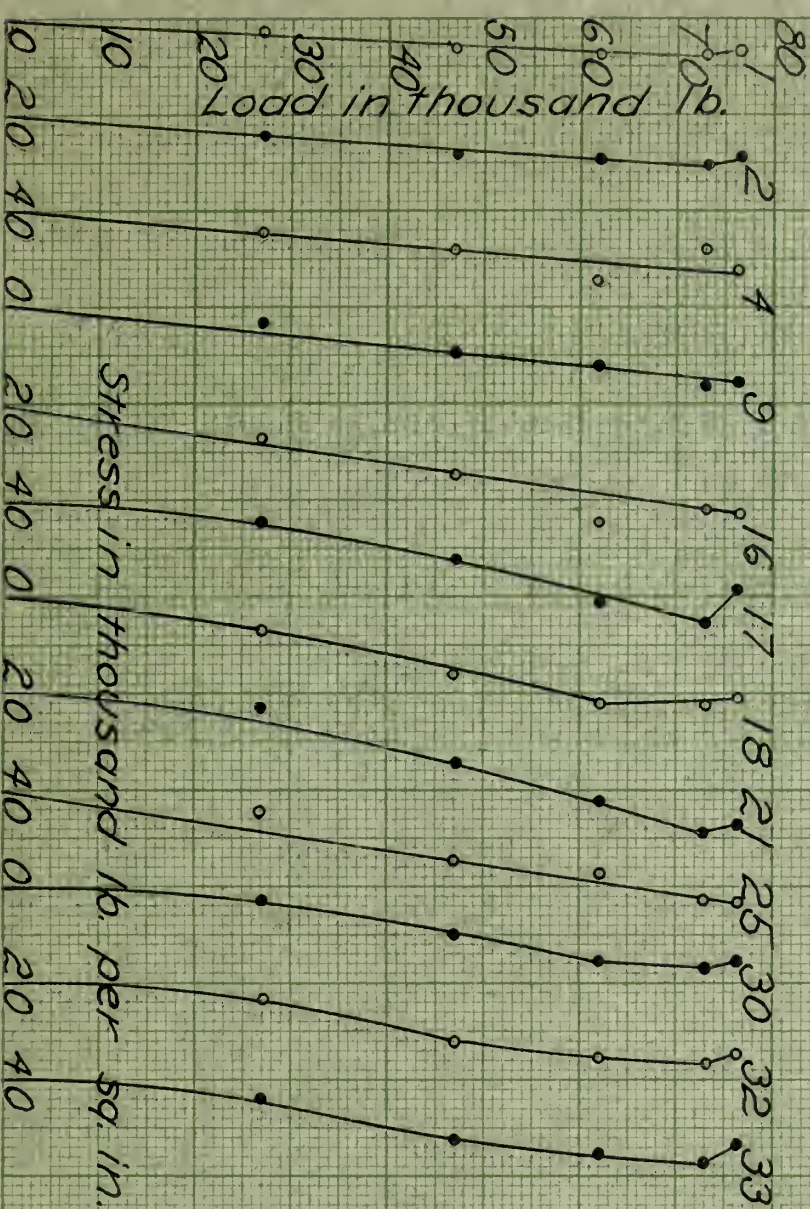
41

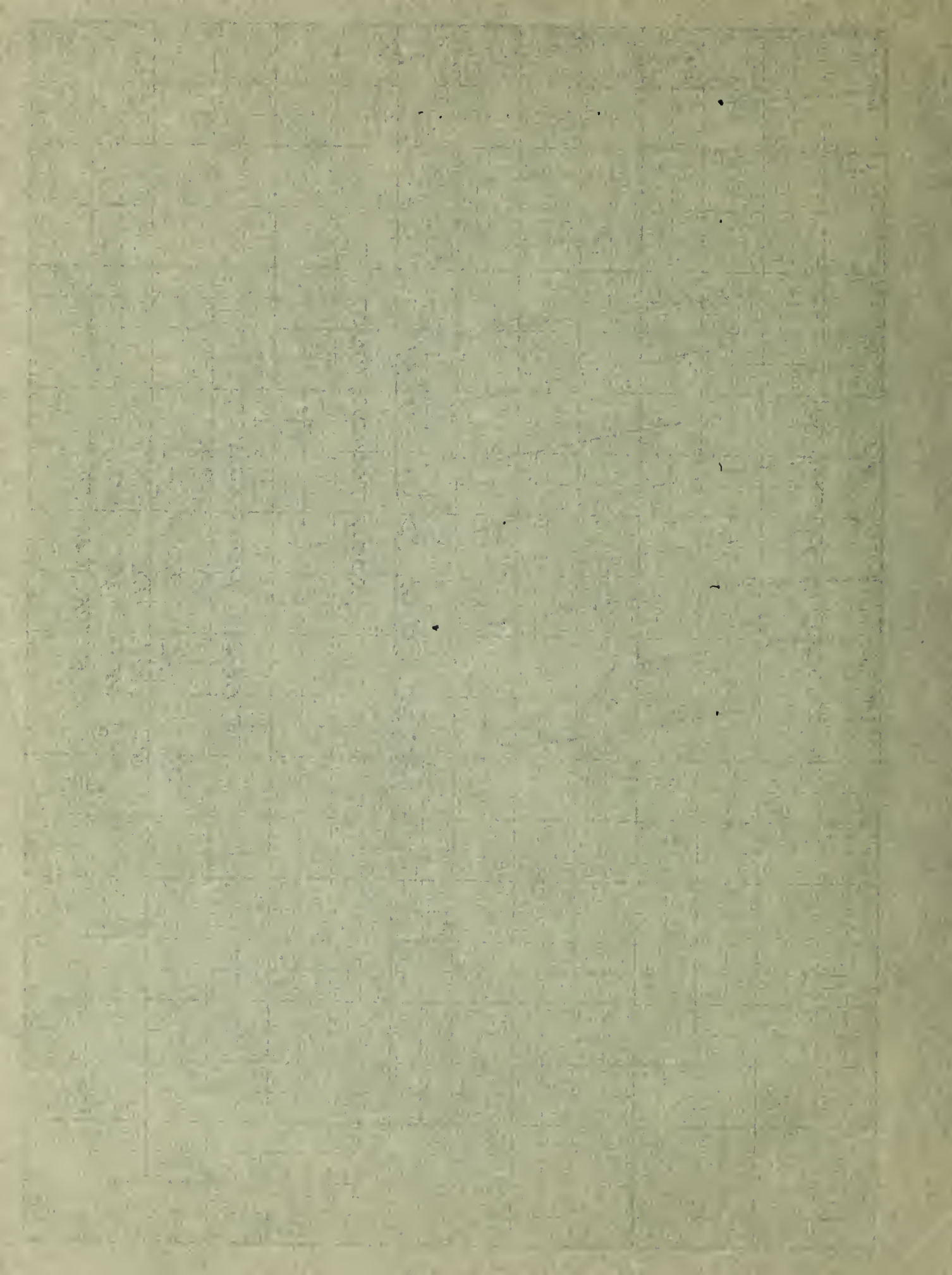
Transverse Rods:



Beam No. 7571
 Rods No. 33 Size 1 1/2" % 1.5
 Long. 33
 Trans. 10 7/16" .78
 Width 72"
 Max. Load 76,500 lb.

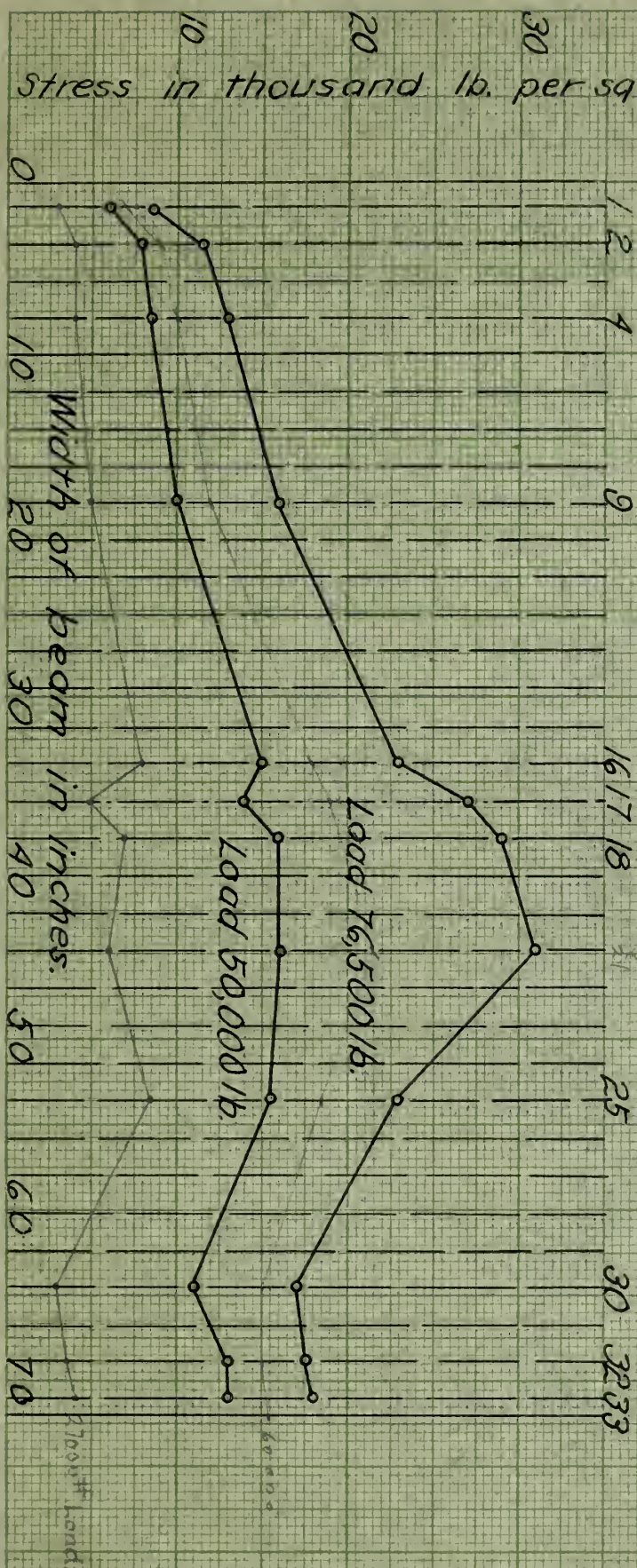
Longitudinal Rods.





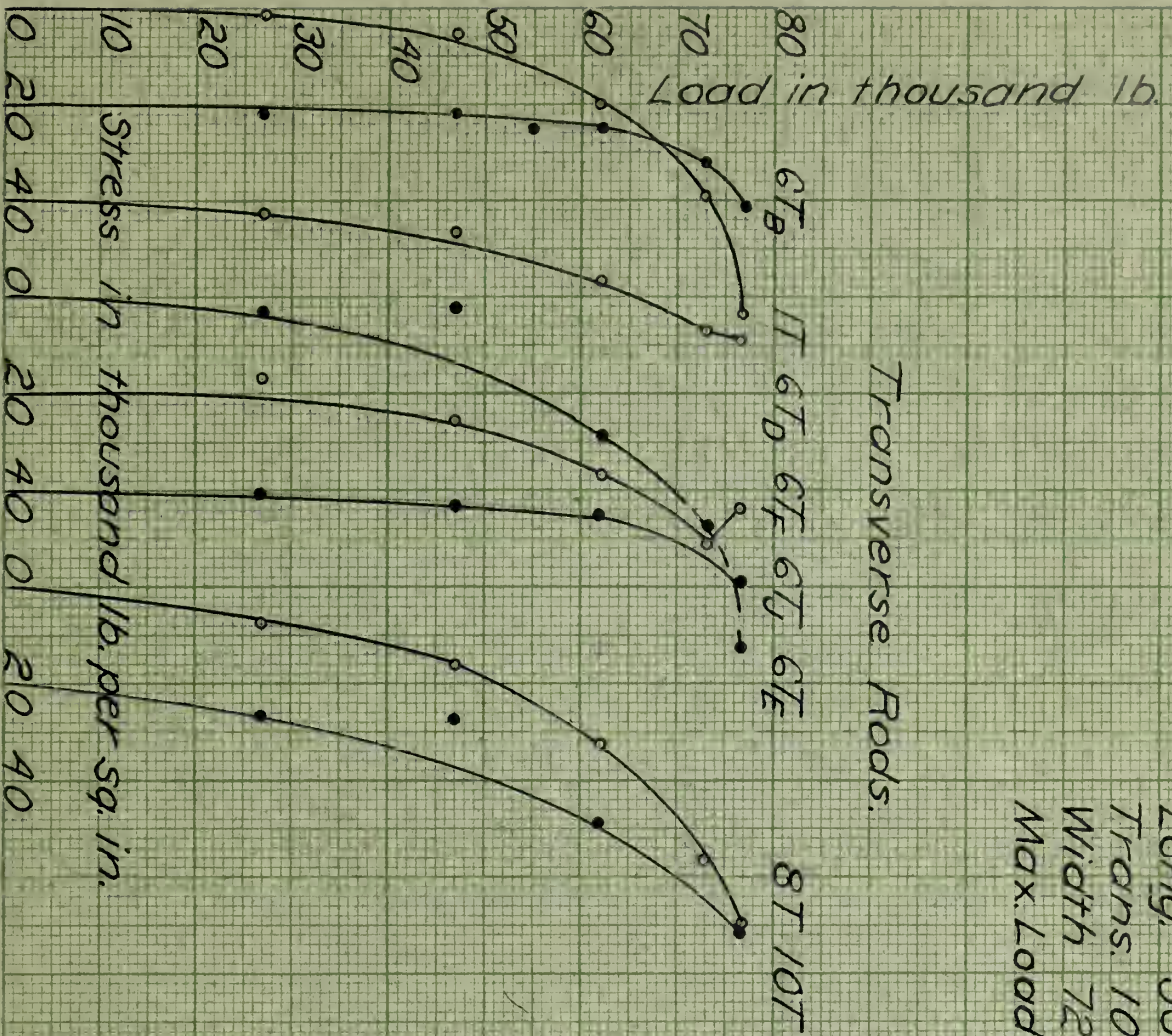
Beam No. 7571
 Rods No. Size %
 Long 33 1/2" 1.50
 Trans. 10 7/16" .78
 Width 72"
 Max. Load 76,500 lb.

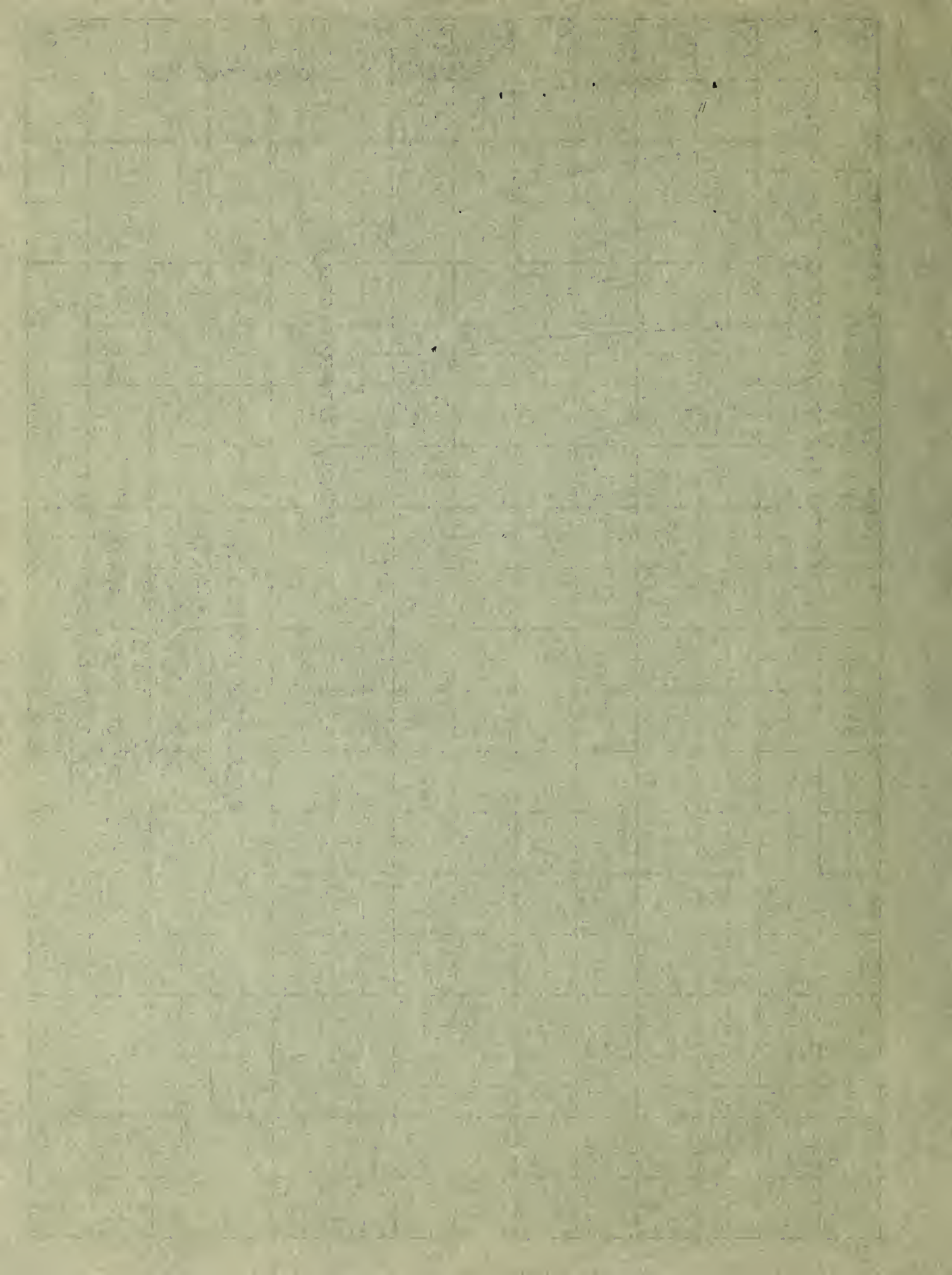
Longitudinal Rods



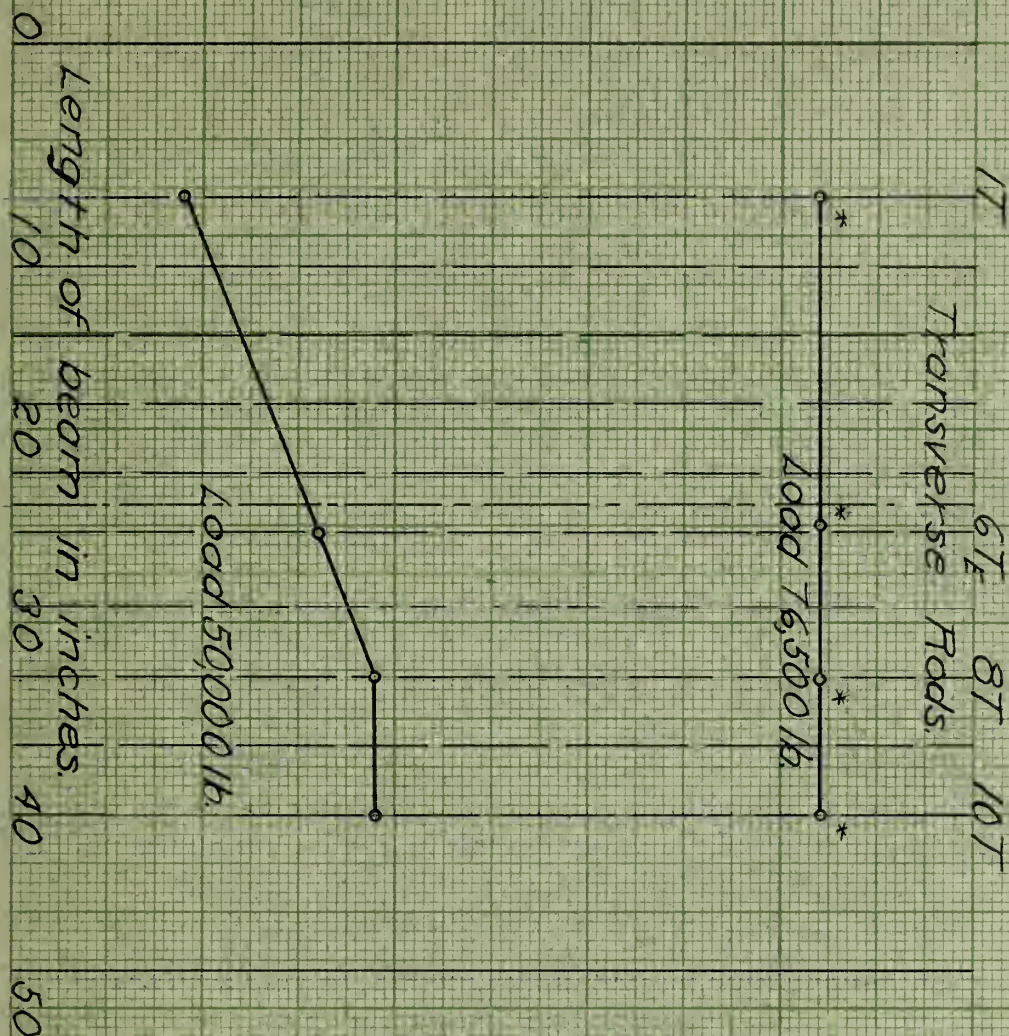
Beam No. 7571
 Rods No. Size %
 Long. 33 1 1/2" 1.5
 Trans. 10 7/16" .78
 Width 7 1/2"
 Max. Load 76,500 lb.

Transverse Rods.





Stress in thousand lb. per sq. in.



Beam No. 7571

Rods No. Size %

Long 33 1/2" 1.5

Trans 10 7/16" .78

Width 72"

Max Load 76,500 lb.

67 87 107

Transverse Rods.

Load 76,500 lb.

Beam No. 757.2
 Rods No. Size %
 Long. 33 1/2" 1.50
 Trans. 13 3/8" .75
 Width 72"
 Max. Load 82,000 lb.

Longitudinal Rods

Transverse Rods

